Aus der Klinik für Allgemein-, Viszeral- und
Kinderchirurgie
der Heinrich-Heine-Universität Düsseldorf
Direktor: Univ.-Prof. Dr. med. Wolfram T. Knoefel

Advances in laparoscopic hernia repair

Habilitationsschrift

zur Erlangung der Venia Legendi für das Fach Chirurgie

des Fachbereichs Medizin der Heinrich-Heine Universität Düsseldorf

vorgelegt von

Dr. med. Dimitrios Prassas

geboren in Lamia

2020

TABLE OF CONTENTS

1.INTRODUCTION

1.1. Brief history of hernia surgery

The word ‚hernia‘ derives from the ancient greek word ‘hernos’ meaning sprout, as it referred to the resemblance of an abdominal wall hernia to the protruding bud of a plant [1]. The first observations regarding hernias appear in the egyptian papyrus of Ebers, dating back to the 16th century B.C [2]. Even though written evidence have not been found, signs of inguinal hernia surgery exist on the mummified body of Pharaoh Merneptah (1224-1214 B.C.) on which a large wound in the groin can be seen, with the scrotum separated from the rest of the torso [3]. Nevertheless, whether hernia repair procedures were performed at that time is still debatable. Nearly a thousand years later, Hippocrates (400 B.C.) described in the ‘Hippocratic Corpus’ the differentiation between hydrocele and inguinal hernia, with the former being transluminable [4]. Hippocrates was also the first to recommend taxis for strangulated hernias. Later, in the age of the Roman Empire, Aulus Cornelius Celsus suggested surgical repair of the symptomatic inguinal hernia through a scrotal incision just below the pubis, with dissection of the hernia sac from the spermatic cord and excision of the former. The use of cauterization was proposed as a method that accelerated the scar formation process [3]. About seven hundred years later, Paul of Aegina suggested ligation of both hernia sac and spermatic cord, sacrificing the ipsilateral testicle; an act that constituted a regression from the classic surgeons of that time [3]. The practice of routine concomitant orchiectomy was rejected again in the Middle Ages by William of Saliceto in 1275 A.D. [5]. As anatomic dissection and autopsy spread throughout the European continent after the Renaissance, the foundation of a more systematic approach on hernia repair was set. Knowledge, accumulated up until the 19th century, led to the complete understanding of the inguinal anatomy and paved the way for the publication of many classic works on the field by prominent anatomists like Scarpa, Cooper and Hesselbach. Nevertheless, despite all of the aforementioned advances, it was not until the introduction of Anesthesia in 1846 and the principles of antiseptic surgery by Lister in 1870 that the groundwork of modern hernia surgery was laid [6].

Various techniques were described at that time, alas with a rather disappointing outcome, as reported by Billroth who reviewed the European experience in 1890 [7]. The surgical approach proposed by Bassini introduced a novel concept of physiological reconstruction of the inguinal canal instead of obliterating it with deep suturing of the inguinal rings. Bassini meticulously followed up with his patients and recorded the lowest morbidity and mortality rates of his time [8]. The next landmark in hernia repair was the utilization of Cooper's ligament, first documented by Georg Lotheissen of Vienna in 1898 [3]. Bassini's approach was widely adopted and was further modified and improved, leading eventually, to the Shouldice repair [9], focusing on a multi-layer repair of the transversalis fascia. It was soon realized that tension on the pubic end of the repair could lead to post-herniorrhaphy pain and recurrence. This observation gave birth to the concept of tension-free hernia repair, an operative strategy that constitutes the gold standard of hernia surgery from the mid-twentieth century up to the present time. The first to ever use a tension-free technique was Wölfler by performing a 'relaxing incision' on the anterior rectus sheath [10]. This technique was later modified and popularized by Anson and Mc Vay in 1960 [11]. An alternative approach to tension-free suture repair is the use of a prosthetic material. Marcy in 1887 was the first to report the use of kangaroo tendon to cover the hernia defect [12]. Subsequently, early forms of mesh were created and implanted in patients. These early meshes were made of stainless steel, characterized by exceptional stiffness, nylon that demonstrated too rapid disintegration, and polypropylene, a material with more favorable properties. The first utilization of a mesh to bridge the hernia defect rather than reinforcing tissues under tension was described by Usher [13]. A further issue that emerged was that of the most appropriate positioning of the mesh. Lichtenstein proposed that the mesh should be implanted anterior to the fascia transversalis, resulting in a paradigm shift in hernia surgery with tension-free repair being accepted as the standard of care [14].

The introduction of laparoscopy revolutionized the field of hernia surgery in the early 1990s with the development of transabdominal pre-peritoneal approach (TAPP) which is, essentially, a laparoscopic hernia sac reposition and implantation of a mesh in a tension-free manner [15]. This technique opened the way for the laparoscopic total extraperitoneal repair (TEP) in 1991 [16], an approach based on the dissection of the

pre-peritoneal space and implantation of a mesh, usually without any form of fixation of the latter. The advances in laparoscopy provided alternative therapeutic strategies for further types of hernias, other than groin hernias, and gave birth to intra-peritoneal mesh implantation techniques as an alternative to the classic open surgical approach for ventral/incisional hernias and also hiatal hernias as well.
The above brief presentation of the history of hernia surgery demonstrates the distance covered between the early days of surgical repair and the modern era of tension-free laparoscopic surgery. Although open repairs have proven themselves over time and still remain the standard approach for many surgeons, laparoscopic hernia repair demonstrates excellent outcomes in the hands of the adequately trained. Nevertheless, a plethora of unanswered questions have yet to be addressed.

1.2. Hernia classification and epidemiology

Hernia refers to any protrusion or projection of an organ, or part of it, through a hernia ring. In the case of abdominal wall hernias this protrusion occurs through the wall that contains the herniated structures. On the contrary, internal hernias occur when the internal organ protrudes into a retroperitoneal fossa or a foramen in the abdominal or thoracic cavity.
The abdominal wall consists of a complex fusion of overlapping layers of muscle and connective tissue designed to contain and protect the abdominal contents while facilitating rotation and approximation of the thorax with respect to the pelvis [17].

Abdominal wall hernias are usually classified by location:

- Ventral hernias

Ventral hernias protrude through the anterior abdominal wall and include primary hernias such as umbilical, epigastric, spigelian, parastomal and the majority of incisional hernias. The general population has a 2-20% lifelong risk of developing an incisional hernia after laparotomy [18]. An estimated 25% of all individuals are either born with or will develop a primary ventral hernia in their lifetime [19].

- Groin hernias

Groin hernias account for approximately 75% of all abdominal wall hernias with a lifetime risk of 27% in males and 3% in females [20]. Groin hernias can be subdivided into inguinal and femoral hernias. Approximately 96% of groin hernias are inguinal and the remaining 4% are femoral [21] which present more frequently as complicated hernias than the former.

- Pelvic hernias

This type of hernias protrude through the pelvic foramina (hernia sciatica, hernia obturatoria) of the perineum. They are relatively rare occurrences with a known incidence of under 0,5%, although the chances are that the real incidence is greater as that reported in the literature [22].

- Flank hernias

Flank hernias occur infrequently and can be congenital, primary, post-traumatic, or incisional. They are bounded by the 12^{th} rib, the iliac crest, the erector spinae and the external oblique muscle. Hernia rates of 0,4-17% following flank incision have been reported [23].

- Hiatal hernias

The term hiatal hernia refers to the herniation of intraabdominal organs through the hiatus oesophagei. In general, four different types of hernias are described. The most common is type I hernia or sliding hernia, where the cardia of the stomach slides cranially above the diaphragm. Type II results from a defect of the phrenico-esophageal membrane where the gastric fundus serves as the leading point of herniation with the gastric junction remaining in position. Type III is a combination of type I and II. Type IV is associated with a large defect of the hiatus oesophagei which allows the herniation of most of the stomach and/or further intraabdominal organs into the mediastinum. More than 95% of hiatus hernias are Type I hernias [24].

1.3. Pathophysiology

Congenital Hernias

The abdominal wall is from a biomechanical point of view a cylinder-like structure comprised of muscle, aponeuroses and connective tissue that contain the viscera intra-peritoneally. Generally, the etiology of herniation can be divided into two categories: congenital and acquired. Failure of the processus vaginalis to obliterate results in a patent inguinal canal and, consequently to indirect groin hernias both in men and women [25]. The processus vaginalis is an invagination of the peritoneum parietalis that facilitates caudal testis migration in males. More specific, in males, the caudal genital ligament (gubernaculum) physiologically migrates through the inguinal canal to the scrotum to allow descent of the testicle. Subsequently, the cranial part of the gubernaculum degenerates and the internal ring closes. The caudal part of the gubernaculum remains and forms the scrotal ligament [26]. Failure of this embryological sequelae leads to a patent processus vaginalis, also named 'canal of Nuck' and formation of a congenital groin hernia. In females, migration of the caudal genital ligament does not occur [27]. Its inguinal component persists in females as round ligament, whereas in males it disappears. It runs through the internal ring, along the inguinal canal and ends in the subcutaneous fat tissue of labium majora or cranial to the external ring.

About 10% of umbilical hernias also have a congenital etiology. Failure of the umbilical fibromuscular ring to obliterate, an ongoing process that can last until the 4th year of life, results in a hernia ring [28] [29].

Although rare, diaphragmatic hernias can also have a congenital etiology that is associated with failure of the diaphragm to completely close during development. Two of the most common congenital diaphragmatic hernias are the hernia of Bochdalek, with postero-lateral localization, and the hernia of Morgagni that occurs on the anterior right side of the diaphragm.

Acquired Hernias

The majority of abdominal wall hernias are acquired. Degeneration or disruption of the fibromuscular structures leading to herniation can develop as a result of various

conditions. Disturbed collagen metabolism plays a decisive role in the formation of hernias. It has been shown that in individuals with altered collagen metabolism the role of fibroblast production is not physiologic and also that the rate of collagenolysis appears to be increased compared to healthy individuals [17]. Acquired elastase deficiency can also lead to hernia formation. It has been found that increased serum elastase and decreased a1 antitrypsin levels are associated with smoking and lead to an increased rate of herniation [17]. Other known risk factors include: chronic glucocorticoid administration and older age.

Chronic increase of the intra-abdominal pressure is a major risk factor that contributes to acquired hernia. Chronic cough, pregnancy, constipation, and strenuous physical activity are all factors that result in elevation of the intra-abdominal pressure. According to Pascal's principle the intra-abdominal pressure is transmitted equally to the abdominal walls. In response to pressure increase, the muscular abdominal wall strata contract, generating counter-pressure. In the event that the intra-abdominal pressure exceeds abdominal wall pressure, the excess pressure results in deformation of the abdominal wall's weakest component [17]. According to the law of Laplace, $T=Pr/w$ where T is wall tension, P is pressure, r is radius and w is wall thickness. The biomechanical interpretation of the above physical law is that the wall tension will be greatest at the area with the largest radius and the thinnest wall. Hence, once a defect has been already developed, the radius at this location will increase and the abdominal wall thickness will have decreased thus increasing wall tension which, subsequently, leads to hernia progression. From all the above, it can now be easily derived that once a hernia defect exists, its progression will be continuous as the wall tension at that point will continue to increase.

1.4. Clinical features

A common symptom of abdominal wall hernias, regardless of their localization, is a dull discomfort or 'heaviness' which may or may not be associated with a bulge. Those hernias are mostly reducible and can also manifest as an asymptomatic, non-tender mass. When visible, the bulge usually increases on straining and completely decreases on lying down. The edges of the fascia defect are always palpable. If moderate to

severe pain is present, the possibility of incarceration or even strangulation should be considered. A hernia is characterized as incarcerated or as irreducible when the hernia contents become adherent to the hernia sac, hindering the reduction in the abdominal cavity. Incarcerated hernias containing a hollow viscus may manifest with symptoms of bowel obstruction. In case of compromised vascular supply, ischemia and necrosis of the herniated tissues may occur. Signs of strangulation include a tender, irreducible hernia, absent cough impulse and an edematous, erythematous warm overlying skin. Depending on the severity of the case, patients may present with a toxic appearance and must be rapidly treated.

Hiatal hernias constitute a distinct type of hernias as the functionality of the lower esophageal sphincter is influenced, producing upper GI symptoms, the most common of which are heartburn, regurgitation and dysphagia. Nevertheless, most type I hiatus hernias, also known as sliding hernias, remain asymptomatic. The most common symptoms of individuals with type II-IV hernias are usually vague and intermittent, including epigastric pain, dysphagia and bloating. Complications of type I hernias are exclusively reflux-associated whereas complications of all paraesophageal and mixed types are associated with mechanical problems caused by the hernia itself. The symptom intensity is usually proportionate to the size of the hernia with the most severe being reported by patients with gigantic type III-IV hernias. [30].

Paraesophageal hernia complications can be life-threatening and include gastric volvulus, respiratory complications and/or palpitations caused by mechanical compression of the thoracic structures and GI bleeding. Bleeding ulcers and erosions of the herniated stomach are described in the literature as Cameron lesions [31]

1.5. Therapy

As mentioned previously, once a hernia ring occurs, its progression will be continuous as the wall tension will permanently increase. The Law of Laplace clarifies the fact that the definitive therapy of a hernia can only be surgical. In the acute setting, hernia reduction may be performed, depending on the type of hernia and presence of incarceration. A strangulated hernia resulting in visceral ischemia renders immediate surgical intervention necessary. Signs of inflammation contraindicate any reduction

attempts. En-bloc reduction of an incarcerated hernia results in the intraabdominal transposition of the strangulated viscus, resulting in the ongoing compromise of the latter and mandates prompt exploration of the abdomen [32]

- Inguinal hernias

Symptomatic patients with hernias should be offered surgical repair to improve their quality of life. Surgical repair is routinely recommended for female patients as the incidence of femoral hernias, a type of hernias with higher risk of serious complications, is higher [33]. Inguinal hernia repair can be performed either open or laparoscopically. Open surgery can be further divided into two subgroups: the suture repair and the tension-free repair in which a prosthetic material is incorporated. The most popular open tension-free repair worldwide is the Lichtenstein repair or one of its modifications such as the 'plug and patch' technique. A key element of the Lichtenstein technique is the implantation of a mesh in the posterior wall of the inguinal canal to create a new artificial internal ring [14]. The Shouldice technique is a popular open suture repair. The central component of this approach is the incision of the transversalis fascia from the internal ring laterally to the pubic tubercle medially and the advancement of two upper and lower flaps which are then overlapped with a double layer of continuous sutures. The choice of repair should be tailored to the clinical circumstances, needs and expectations of each patient. Both tension-free and sutured repairs have advantages in experienced hands and in the correct setting. Since its introduction, laparoscopic hernia repair has gained increasing acceptance among surgeons worldwide, despite of its relatively long learning curve [34]. Laparoscopic transabdominal pre-peritoneal repair (TAPP) first described in 1990 [16] followed by the introduction of total extraperitoneal repair (TEP) [15] one year later, are two well-established approaches with widely documented outcomes with minimal post-operative pain and dropping of recurrence rates at 2-3% [35].

TAPP

TAPP repair is performed through a transperitoneal access and, contrary to the TEP approach, is a true laparoscopic procedure. Once the primary trocar and the two

working trocars are inserted, the peritoneum is then incised to a point medial to the anterior superior iliac spine 2 cm cranially in relation to the internal inguinal ring, on the herniated side. Then, the pre-peritoneal space is exposed. The spermatic cord is then mobilized and the peritoneum is dissected proximal to the point of bifurcation of the spermatic vessels. In this manner, reduction of the hernia sac takes place. Afterwards, a prosthetic mesh is placed so that the myopectineal orifice is covered in its entirety. Mesh material and mesh fixation are still matters of controversy. The last step of the operation is the closure of the peritoneal defect and, consequently, the isolation of the foreign prosthetic material from the intraperitoneal viscera.

TEP

Total extraperitoneal repair commences with the development of the pre-peritoneal space with the insufflation of a spherical-shaped balloon dilatator followed by blunt and/or sharp dissection when necessary, after visualization of the posterior rectus sheath and retraction of the rectus muscle. The two additional working trocars are then inserted into the expanded myopectineal orifice. Once this space has been accessed, the spermatic cord dissection and hernia reduction proceeds in a fashion identical to the TAPP repair. It is of paramount importance that all potential points of herniation must have the mesh extending at least 2 cm beyond them in all directions. The medial extent of the mesh should be aligned with or even pass the midline. In case of bilateral repairs, the two meshes should overlap over the middle. That is because the medial extent of larger defects can extend to 2 cm off the midline. Once the mesh has been placed, the pneumoperitoneum is evacuated. Unlike the TAPP repair, closure of the peritoneum is not necessary, as it has not been violated.

- Ventral/Incisional Hernias

Both primary and secondary (incisional) ventral hernias can be surgically repaired either open or laparoscopically. Open suture repair was the gold standard of care for many years until data demonstrating recurrence rates up to 63% emerged [36]. This paved the way for mesh utilization which was associated with significantly lower recurrence rates on long-term follow-up [37]. As mesh implantation gained acceptance, various anatomical sites of implantation were used. The prosthetic

material can be placed ventral to the fascia (onlay), between the rectus muscles and the peritoneum (sublay), dorsal to the peritoneum (underlay or intraperitoneal onlay also known as IPOM) or as a bridge between the edges of the fascia defect (inlay). Existing data associate sublay and IPOM mesh placement with lower recurrence rates [38]. Ventral/Incisional hernias with a maximal defect width above 10 cm are classified as large hernias by the European hernia society and are associated with a notable level of complexity regarding their surgical management [39]. Fascia approximation in this category of cases is either impossible or is achieved only on the cost of high tension. Bridging of the hernia defect with a prosthetic material remains an option but, it should be kept in mind that it cannot restore the dynamic functionality of the abdominal wall. Therefore, when possible, a different approach such as component separation should be taken into consideration. The introduction of component separation has facilitated our capability of repairing more complex hernias of the anterior abdominal wall. Ramirez was the first to describe this technique in the year 1990 [40]. The principle of his approach is the separation of the abdominal wall muscle layers in order to enable the midline excursion of the rectus abdominis. More specifically, the separation commences with the division of the medial attachment of the external oblique muscle, followed by the separation of the latter from the internal oblique muscle. Then, the posterior rectus sheath is mobilized followed by closure of the linea alba. Endoscopic component separation is also an option although it provides less release compared to the standard open procedure. A balloon dilatator is placed underneath the external oblique muscle and passed caudally toward the inguinal ligament. The balloon is insufflated and a space between the two muscles is created. Then the external oblique muscle is incised. Care should be taken to complete the release lateral to the linea semilunaris. However, in cases with previous transverse incisions of the lateral abdominal wall, the balloon dissector will tear the abdominal wall in the presence of excessive scar tissue, making the endoscopic approach contraindicated.

Laparoscopic techniques-IPOM

Since the introduction of the laparoscopic approach in ventral hernia repair by Leblanc and Booth in 1993 [41], the laparoscopic IPOM technique has been widely accepted as

it offers at least comparable outcomes to open surgery [42]. The procedure is generally performed in a three-trocar technique. The first step, specifically in cases with incisional hernia, is adhesiolysis which may take up the majority of the operative time. Adhesiolysis should generally be performed using blunt and sharp dissection. Use of energy sources should be avoided as they could either cause a primarily visible lesion of a hollow organ or could cause a lateral spread of thermal energy, potentially causing a secondary bowel perforation and a delayed intestinal leak. A recognized bowel lesion at the time of the index operation is associated with a mortality rate up to 1,7% whereas a secondary perforation with a mortality rate up to 7,7% [43] [44]. At least 5 cm of peritoneal surface must be freed of adhesions on either side of the hernia ring to allow a satisfactory overlap of the prosthetic material with the healthy fascia. Reduction of the hernia contents can be either straightforward or challenging. Generally, reduction of chronically incarcerated hernias should be performed in a hand-over-hand manner, with the application of external pressure if needed. In cases where the pre-peritoneal contents cannot be completely reduced, the peritoneum is incised around the fascia defect and the pre-peritoneal fat is reduced en bloc with the protruding hernia sac. At this point the fascia defect can be primarily closed allowing wider lateral mesh overlap and eliminating dead space. The necessity of this practice is debated [45]. A further controversial topic is that of the most appropriate way to reduce postoperative seroma rates. Mesh insertion and fixation is the next and most fundamental step of laparoscopic IPOM repair. It is crucial that the distance between the fascia defect and the edge of the mesh is at least 5 cm long. The mesh then can be fixated either with use of transfascial sutures or tacks in double-crown technique (the first row of tacks encircling the hernia ring and the second row of tacks being placed at the perimeter of the mesh). Discussions concerning the optimal tack and mesh material are still ongoing.

- Paraesophageal Hernias

Surgical repair of paraesophageal hernias is generally indicated in all symptomatic patients [46]. Paraesophageal hernias can be repaired either transabdominally or transthoracically. The transabdominal approach can be either open or laparoscopic. In

the hands of experienced surgeons recurrence rates are similar, however, laparoscopy is associated with reduced perioperative morbidity and mortality, less postoperative pain and shorter hospital stay [47]. Regardless of the approach, paraesophageal hernia repair involves a standard sequence of operative steps. Initially, the hiatus and hernia sac must be dissected with great care to avoid injury to adjacent structures such as pleura and aortic arch. The stomach is then repositioned and the lower esophagus must be sufficiently mobilized, usually 3-4 cm intraabdominally to ensure a tension-free repair. After complete esophageal dissection, the next step is closure of the hiatal defect. This can be either performed with a suture hiatoplasty alone or with a mesh reinforcement. The type of hiatoplasty, use of prosthetic material, type, configuration and fixation of the latter remain debatable.

The functional impairment of the lower esophageal sphincter can be dealt with, with the inclusion of an anti-reflux procedure as part of the paraesophageal hernia repair. The decision to perform a fundoplication should generally depend on the esophageal functional status of the patient, taking into consideration the high risk of post-operative dysphagia.

An anterior gastropexy should be used to reduce the risk of re-herniation intrathoracically. Recent studies reveal that even in the absence of fundoplication the incidence of post-operative reflux is acceptable with gastropexy alone [48].

1.6. Purpose

The aim of this cumulative work is to shed light on current controversial issues of laparoscopic hernia surgery that largely remain unstudied.

- The first question addressed was that of the efficacy and safety of laparoscopic giant hiatal hernia repair. This paper focused on posterior suture hiatoplasty as a method of choice for crural closure of large hiatal defects. [Appendix A] [49]

- The choice of prosthetic material in laparoscopic TEP repair of inguinal hernias was a further direction of the conducted research. Even though a plethora of hernia repair mesh products are commercially available, there is no definitive

proof that one type of mesh is more appropriate than the other. The aim of this paper [Appendix B] [50] was to compare the outcomes after TEP using a standard-weight prolene mesh or a lightweight Titanium-coated mesh with regard to perioperative morbidity, postoperative pain, chronic inguinal pain occurrence and hernia recurrence.

- A further subject of interest regarding laparoscopic TEP hernia repair is that of the appropriateness of the method among patients with prior surgery of the lower abdomen. Initially the feasibility and safety of TEP in this patient group was investigated in a cohort study [Appendix C] [51]. Further data was then generated with the conduction of a meta-analysis [Appendix D] [52] which additionally clarified the above-mentioned issue and examined if the findings of paper C can be generalized beyond this study itself.

- Moving to the laparoscopic IPOM ventral/incisional hernia repair, a novel method of electric cauterization of the hernia sac without closure of the hernia defect was suggested as a simple measure against post-operative seromas. The hypothesis was tested in a cohort study with propensity score matching [Appendix E] [53].

2.RESULTS

2.1 Laparoscopic repair of giant hiatal hernia. A single center experience. [Appendix A] [49]

The aim of this paper was to investigate the efficacy and safety of the laparoscopic approach in patients with large type III and IV hiatal hernias. Between the years 1997 and 2012 fifty-five patients with giant hiatal hernias were treated. In just a single case a prosthetic material was used to reinforce the approximated crurae. In the remaining fifty-four cases, a posterior suture hiatoplasty was performed in a standardized technique. Follow-up was conducted via a mailed questionnaire consisting of 21 close-ended questions regarding patient-reported outcome and quality of life. Laparoscopic repair was successful in 98,1% (54/55) of the cases. The only conversion to open surgery was necessitated by a massive hepatomegaly minimizing the operative situs. Intraoperative complications occurred in one patient who suffered from pneumothorax. The median operative time was 96 minutes (range: 30-350). The median hospital stay was 9 days (range: 4-20). Overall 30-d Morbidity was found to be at 14,5% (8/55). The median duration of follow-up was 64 months (range: 4-176). The difference between pre- and post-operative symptom intensity was found to be significant for heartburn ($p<0,001$) and retrosternal/epigastric pain ($p<0,05$). The difference was found to be insignificant for dysphagia and bloating. The majority of questioned patients assessed the decision to undergo surgery as correct [89,5%, (16/19)].

International Journal of Surgery 20 (2015) 149–152

Contents lists available at ScienceDirect

International Journal of Surgery

journal homepage: www.journal-surgery.net

Original research

Laparoscopic repair of giant hiatal hernia. A single center experience

Dimitrios Prassas*, Thomas-Marten Rolfs, Franz-Josef Schumacher

Katholisches Klinikum Oberhausen, Department of Surgery, Teaching Hospital of the University of Duisburg-Essen, Germany

HIGHLIGHTS

- Patients with giant hiatus hernias were studied.
- Efficacy and safety of laparoscopic giant hiatal hernia repair on a routine basis in a small community hospital.
- Good symptom control, high patient satisfaction, improved overall quality of life.

ARTICLE INFO

Article history:
Received 17 June 2015
Accepted 19 June 2015
Available online 6 July 2015

Keywords:
Giant hiatal hernia
Upside-down stomach
Large hiatal hernia
Laparoscopic hiatal hernia repair

ABSTRACT

Introduction: Giant hiatal hernia is a rare clinical entity with possibly serious complications, diagnosed mostly among older patients. The laparoscopic repair of such hernias is a therapeutic option, performed mostly in specialized centers by experienced surgeons.

Methods: From 1997 to 2012 fifty-five patients with giant hiatal hernia (median age of 72) were primarily treated by laparoscopic surgery at the surgical department of the Catholic Clinic Oberhausen. Demographic data, operating times, conversion rate, morbidity and mortality were recorded prospectively. Follow-up was conducted by means of a mailed questionnaire.

Results: Intraoperative complications occurred in 1,8% of the cases (n = 1). In this single case the procedure was converted to an open procedure due to technical difficulties imposed by hepatomegaly. The median operating time was 96 min (range, 30 to 350). Our rate of postoperative complications was 14,5% (n = 8). The median postoperative hospital stay was nine days. 14,5% (n = 8) of our patients underwent a redo-surgery for symptomatic recurrence. The median follow-up was 64 months by means of a self-designed questionnaire. 34,5% (19/55) of the questioned patients responded to our survey. The difference between pre- and postoperative symptom intensity was found to be significant for heartburn ($p < 0,001$) and retrosternal/epigastric pain ($p = 0,028$). The difference was not found to be statistically significant for dysphagia ($p = 0,8$) and bloating ($p = 0,3$).

85% of the questioned patients stated they would have the operation again, if necessary. 80% reported an improvement of their overall quality of life.

Discussion: The laparoscopic repair of large hiatal hernias is a safe approach with an intraoperative complication rate of 1,8%, low post-operative morbidity (14,5%) and very low mortality (1,8%). There is a high patient satisfaction (85%) and a good postoperative quality of life (80%).

Conclusion: The laparoscopic approach for repair of large hiatal hernias is a relatively safe method with significant long-term efficacy in terms of symptom control and quality of life.

1. Introduction

The term Hiatus Hernia refers to the herniation of intra-abdominal organs through the hiatus oesophagei. A rare form of this type of hernia is the Upside-down-stomach [1]. In general, four types of hernias are described. The most common one is type I hernia or sliding hernia, where the cardia of the stomach slides cranially above the diaphragm. Type II results from a defect of the phrenicoesophageal membrane where the gastric fundus serves as the leading point of herniation, with the gastric junction remaining in position [2]. Type III is a combination of the two aforementioned types where both cardia and fundus are protruding into the mediastinum. This group of patients may suffer from both heartburn and mechanical symptoms. Type IV is associated with a large

* Corresponding author. Nürnberger Str. 10, 46117 Oberhausen, Germany.
E-mail address: dimitrisprassas@yahoo.gr (D. Prassas).

http://dx.doi.org/10.1016/j.ijsu.2015.06.067
1743-9191/

defect in the phrenicoesophageal membrane, which allows the herniation of most of the stomach and/or other intraabdominal components. The Upside-down-stomach, or intrathoracic stomach is a form of type IV hernia.

In contrary to patients with paraesophageal and mixed types of hiatus hernias, most individuals diagnosed with sliding hernias remain asymptomatic. Large hernias impose a risk of life threatening complications such as bleeding ulcerations, strangulation and perforation [3]. With conservative management alone such cases demonstrate mortality rates up to 27% [4]. Thus, the elective surgical management of eligible patients is highly recommended.

Herein, we evaluate the results of laparoscopic surgical repair of large and giant type III–IV hiatal hernias performed in our community hospital between the years 1997 and 2012. The aim of our study was to evaluate the efficacy and safety of the laparoscopic repair of large hiatus hernias, as well as the quality of life, patient satisfaction and symptom control prospectively.

2. Materials and methods

2.1. Patient population and data collection

Between 1997 and 2012, fifty five patients with large hiatus hernia were treated laparoscopically. In most cases, a posterior hiatoplasty was combined with a Nissen Fundoplication without any gastropexy (n = 48). Four patients underwent the aforementioned procedure combined with a gastropexy and three patients underwent a posterior hiatoplasty combined with fundopexy, without construction of any type of fundoplication. A mesh augmentation of the esophageal hiatus was performed in a single case.

Patient data were collected from our institutions'medical records manually for those operated between 1997 and 2006 and electronically from our computer-based patient records database for those operated after 2006.

Our preoperative diagnostic workup consisted of chest X-ray, gastroscopy, barium meal and, in some cases, thorax CT and pH-metry/Manometry.

2.2. Operation

All operations were performed with the lower extremities abducted and the patients in a reverse-Trendelenburg position. The operating surgeon was standing on the right side of the patient and the first assistant between the legs. The second assistant was positioned on the left side of the surgeon. A capnoperitoneum was created with the insertion of a Veress-needle. Our primary 10 mm trocar was inserted 2–4 cm supraumbilically. Four more trocars were then inserted under direct visualization in the upper abdomen. The liver was retracted and the hiatus oesophagei was exposed. The stomach was repositioned and the hernia sac was dissected and reduced from the mediastinum using a harmonic scalpel. Our goal was to dissect the herniated stomach and allow a 3–4 cm of esophageal reposition intra-abdominally. Subsequently, the diaphragmatic crurae were exposed, followed by the skeletonisation of the great curvature, from corpus to fundus. Our next step was the posterior hiatoplasty using 2–3 non-absorbable interrupted sutures, knotted intracorporally. In only one case, where the tension-free approximation of the crurae was not possible, an ultra-pro mesh was implanted. 87% (48/55) of the performed operations were completed with a Nissen fundoplication. The dorsal surface of the fundic wrap was sutured on the right diaphragmatic crus to prevent herniation. The last six procedures of the cohort were completed with a fundopexy being performed with 2–3 non-absorbable interrupted sutures.

Solid food intake was commenced after a radiological control by means of a barium meal, usually between the third and fifth postoperative day in order to exclude early complications such as leakage and pathological passage.

2.3. Follow up

All patients received a questionnaire by mail, consisting of 21 close-ended questions. They were asked to assess the severity of their pre- and post-operative symptoms in a ten-point Likert scale. In addition, the patients were asked questions about their level of satisfaction and postoperative quality of life. We received nineteen out of fifty-five sent questionnaires between May 2014 and July 2014.

2.4. Statistics

The matched pairs t-test was used to calculate statistical significance between pre- and postoperative symptom-scores.

2.5. Ethics

The study was approved by the ethics Committee of the medical faculty of the Heinrich-Heine University of Düsseldorf. An informed consent was obtained from all patients.

3. Results

The study included 55 Patients who were laparoscopically treated for a giant hiatal hernia between September 1997 and December 2012. The baseline characteristics of the study population are presented in Table 1.

3.1. Type of operation

Forty-eight patients underwent a posterior hiatoplasty combined with a Nissen fundoplication. Four of those patients underwent additionally a fundopexy. In three patients posterior hiatoplasty combined with gastropexy, without any kind of fundoplication, was performed. A mesh enhancement of the hiatoplasty was carried out in one of the above patients due to the inability to construct a tension free adaptation of the crurae diaphragmaticae Table 2.

3.2. Intraoperative complications

Laparoscopic repair was successful in 98,1% (n = 54) of the cases. The only conversion to an open repair was performed due to technical difficulties imposed by massive hepatomegaly.

Table 1
Baseline characteristics.

Age, mean (SD) in years	67,5 (SD = 12,3)
Sex (Male/Female)	13/42
ASA Classification	
I	0
II	30,9% (n = 17)
III	49,1% (n = 27)
IV	1,8% (n = 1)
BMI, mean (SD)	29,7 (SD = 6,3)
Underweight	1,8% (n = 1)
Normalweight	10,9% (n = 6)
Overweight	45,5% (n = 25)
Obese Class I	14,5% (n = 8)
Obese Class II	7,3% (n = 4)
Obese Class III	7,4% (n = 4)

Table 2
Operative data and short surgical Outcome.

Laparoscopic Hiatoplasty and Nissen Fundoplication	85,5% (n = 47)
Laparoscopic Hiatoplasty and Nissen Fundoplication with Fundopexy	7,3% (n = 4)
Laparoscopic Hiatoplasty and Fundopexy	5,5% (n = 3)
Laparoscopic mesh Hiatoplasty and Nissen Fundoplication	1,8% (n = 1)
Operation Time min, median (range)	96 (30–350)
Intraoperative Complications	1,8% (n = 1)
Conversion to open Surgery	1,8% (n = 1)
30-d Morbidity	14,5% (n = 8)
Gastric emptying delay	3,6% (n = 2)
Paraesophageal abscess	3,6% (n = 2)
Persistent Dysphagia	1,8% (n = 1)
Respiratory Insufficiency	1,8% (n = 1)
Bilateral pleural effusion	1,8% (n = 1)
Early postoperative recurrence	1,8% (n = 1)
30-d Reoperation rate	5,5% (n = 3)
Median postoperative Hospital-stay, days, (range)	9 (4–20)
30-d Mortality	1,8% (n = 1)

Intraoperative complications occurred in one patient who suffered from a left pneumothorax after an excessive hiatal dissection of the hernia sac. The lesion was intraoperatively identified and a pleural drainage was inserted. The median operating time was 96 min (Range: 30–350 min). The median postoperative hospital stay was 9 days (Range: 4–20 days). The patient with the longest hospital stay suffered from prolonged gastric atony.

3.3. Morbidity and mortality

We had a 30-day postoperative morbidity rate of 14,5% (n = 8). Complications included one patient with persistent dysphagia (1,8%) who eventually underwent pneumatic dilatation, one with bilateral pleural effusions (1,8%), two with gastric emptying disorder (3,6%), two with paraesophageal abscess of the distal esophagus (3,6%) and one with early recurrence of intrathoracic stomach (1,8%). The last three cases were reoperated during their hospital stay. One patient (1,8%) died from respiratory insufficiency within the first post-operative month; his death was not related to intraoperative complications.

3.4. Follow up

34,5% (19/55) of the operated patients participated in the questionnaire-based follow-up. Twenty patients had already deceased. The remaining 16 had changed their address and their personal contact data could not be found.

The median duration of the follow-up period was 64 months (4–176). The difference between pre- and postoperative symptom intensity was found to be significant for heartburn ($p < 0,001$) and retrosternal/epigastric pain ($p = 0,028$). The difference was not found to be statistically significant for dysphagia ($p = 0,8$) and bloating ($p = 0,3$).

As many as 16 out of 19 patients (84,2%) characterized their overall postoperative quality of life as ‚'better' or 'much better'. Seventeen out of 19 patients (89,5%) assessed the decision to undergo surgery as correct Table 3.

Table 3
Pre- and postoperative symptom score (0 min–10 max), SD: Standard Deviation.

Symptom	Preoperative score	Postoperative score	*p*
Heartburn	5,2 (SD = 3,6)	0,2 (SD = 0,7)	<0,001
Epigastric Pain	3,63 (SD = 3)	1,42 (SD = 2,7)	0,028
Bloating	3,55 (SD = 3)	2,61 (SD = 3,4)	0,27
Dysphagia	2,47 (SD = 3,3)	2,26(SD = 3,59)	0,81

4. Discussion

Paraesophageal and giant hiatal hernias represent uncommon type of hernias, accounting for approximately 5% of all hiatal hernias. Medical treatment mostly addresses the reflux components that may exist, whereas most of the patients remain asymptomatic [5]. Left untreated, an unsymptomatic paraesophageal hernia has a probability of developing acute symptoms, and consequently requiring emergent surgery that is calculated at 1,1% whereas the mortality rate of an elective surgical repair is 1,4%, which argues a prophylactic repair. On the contrary, large hiatal hernias show a high incidence of incarceration up to 5% and, left untreated, mortality rates up to 27% [4].

4.1. Surgical technique

Laparoscopy has become common practice in the surgical repair of large hiatal hernias, despite the lack of randomized studies demonstrating its superiority to open surgery. Nevertheless, there exists an ongoing debate regarding key details of surgical technique.

4.1.1. Dissection of the hernia sac

Dissection and reduction of the hernia sac is of paramount importance. The sac has to be inverted, opened into the areolar plane of the mediastinum and dissected circumferentially, leaving a wide margin to cover the crurae [5]. This step not only allows for a 3–4 cm of esophagus to be repositioned intraabdominally, but also significantly reduces the difficulty of a subsequent reoperation, if such is needed. If, nevertheless, a short esophagus is encountered, it is suggested that a collis gastroplasty is performed, a practice of increased complexity associated with a small but significant risk of stapler line insufficiency [6]. In our cohort, no case of short esophagus was encountered, which supports other reports that short esophagus is an uncommon problem' [7].

4.1.2. Closure of the hiatal defect

The proper closure of the hiatal defect is also a fundamental aspect of the surgical repair. Inadequate crural closure with subsequent hernia recurrence and/or migration of the fundic wrap is the most common complication leading to revisional surgery [8]. The hiatoplasty is classically performed by means of adapting the hiatal crurae with non-absorbable interrupted sutures. An alternative approach is the tension-free closure of the hiatal defect with mesh reinforcement, a practice incorporated to reduce the relatively high rate of recurrence. To date, there exist four randomized studies in the literature demonstrating mixed results [9–12] The three first studies take into account radiological and not just clinical recurrences. Additionally, without any standardization of the technique (Mesh shape, mesh material, mesh fixation etc.) the results remain unclear. Most importantly, any benefits of mesh enhancement should be balanced against the risk of mesh-related complications such as stenoses with dysphagia and esophageal erosions [13]. Considering the life-threatening complications we proceeded with mesh implantation in just one case.

4.1.3. Fundoplication

Routine fundoplication as a step in the large hiatal hernia repair operation is controversial. It is believed that those patients have an incompleteness of the lower esophageal sphincter [14]. Moreover, the extensive dissection of the hiatus esophagei could play a role in the function of the lower esophageal sphincter. The conclusions from existing studies are mixed [15,16]. Most of our patients

underwent a Nissen fundoplication. In the process, we gradually changed our operative practice, omitting the fundoplication and performing a hiatoplasty combined with fundopexy.

4.1.4. Fundopexy

The fundopexy was routinely performed in the era of open repair of hiatal hernias. Recent studies of the laparoscopic repair reached the conclusion that the fundopexy significantly reduces the recurrence of hernias, a statement adopted by the SAGES Guidelines fort he Management of Hiatal Hernia [17].

5. Conclusions

Laparoscopic repair of giant hiatal hernias is a safe and effective approach demonstrating low postoperative morbidity and very low mortality when performed with respect to key technical details, showing high patient satisfaction and a good postoperative quality of life.

Ethical approval

Ethics committee University of Düsseldorf. Study Number: 4449.

Funding

Private funding.

Author contribution

Dimitrios Prassas - study design, data collections, data analysis, writing.

Thomas – Marten Rolfs – study design.

Franz – Josef Schumacher – study design.

Conflict of interest

None.

Guarantor

Dimitrios Prassas.

Research registry

Researchregistry 263.

References

[1] C.D. Smith, D.A. McClusky, M.A. Rajad, A.B. Lederman, J.G. Hunter, When fundoplication fails: redo? Ann. Surg. 241 (6) (2005) 861–871.
[2] A.P. Weston, Hiatal hernia with Cameron lesions and erosions, Gastrointest. Endosc. Clin. N. Am. 6 (4) (1996 Oct) 671–679.
[3] H.J. Larusson, U. Zingg, D. Hahnloser, K. Delport, B. Seifert, D. Oertli, Predictive factors for morbidity and mortality in patients undergoing laparoscopic paraesophageal hernia repair: age, ASA score and operation type influence morbidity, World J. Surg. 33 (5) (2009 May) 980–985.
[4] F.W. Obeidat, R.A. Lang, A. Knauf, M.N. Thomas, T.K. Hüttl, N.P. Zügel, K.W. Jauch, T.P. Hüttl, Laparoscopic anterior hemifundoplication and hiatoplasty for the treatment of upside-down stomach: mid- and long-term results after 40 patients, Surg. Endosc. 25 (7) (2011 Jul) 2230–2235.
[5] M.B. Antonoff, J. D'Cunha, R.S. Andrade, M.A. Maddaus, Giant paraesophageal hernia repair: technical pearls, J. Thorac. Cardiovasc. Surg. 144 (3) (2012 Sep) S67–S70.
[6] M.B. Orringer, H. Sloan, Complications and failings of the combined Collis-Belsey operation, J. Thorac. Cardiovasc. Surg. 74 (5) (1977 Nov) 726–735.
[7] B.K. Oelschlager, K. Yamamoto, T. Woltman, C. Pellegrini, Vagotomy during hiatal hernia repair: a benign esophageal lengthening procedure, J. Gastrointest. Surg. 12 (7) (2008 Jul) 1155–1162.
[8] F.A. Granderath, U.M. Schweiger, R. Pointner, Laparoscopic antireflux surgery: tailoring the hiatal closure to the size of hiatal surface area, Surg. Endosc. 21 (4) (2007 Apr) 542–548. Epub 2006 Nov 14.
[9] C.T. Frantzides, A.K. Madan, M.A. Carlson, G.P. Stavropoulos, A prospective, randomized trial of laparoscopic polytetrafluoroethylene (PTFE) patch repair vs simple cruroplasty for large hiatal hernia, Arch. Surg. 137 (2002) 649–652.
[10] F.A. Granderath, U.M. Schweiger, T. Kamolz, K.U. Asche, R. Pointner, Laparoscopic Nissen fundoplication with prosthetic hiatal closure reduces postoperative intrathoracic wrap herniation: preliminary results of a prospective randomized functional and clinical study, Arch. Surg. 140 (2005) 40–48.
[11] B.K. Oelschlager, C.A. Pellegrini, J. Hunter, N. Soper, M. Brunt, B. Sheppard, B. Jobe, N. Polissar, L. Mitsumori, J. Nelson, L. Swanstrom, Biologic prosthesis reduces recurrence after laparoscopic paraesophageal hernia repair: a multicenter, prospective, randomized trial, Ann. Surg. 244 (2006) 481–490.
[12] D.I. Watson, S.K. Thompson, P.G. Devitt, L. Smith, S.D. Woods, A. Aly, S. Gan, P.A. Game, G.G. Jamieson, Laparoscopic repair of very large hiatus hernia with sutures versus absorbable mesh versus nonabsorbable mesh: a randomized controlled trial, Ann. Surg. 261 (2) (2015 Feb) 282–289.
[13] R.J. Stadlhuber, A.E. Sherif, S.K. Mittal, R.J. Fitzgibbons Jr., L. Michael Brunt, J.G. Hunter, T.R. Demeester, L.L. Swanstrom, C. Daniel Smith, C.J. Filipi, Mesh complications after prosthetic reinforcement of hiatal closure: a 28-case series, Surg. Endosc. 23 (6) (2009 Jun) 1219–1226.
[14] C.B. Fuller, J.A. Hagen, T.R. DeMeester, J.H. Peters, M. Ritter, C.G. Bremmer, The role of fundoplication in the treatment of type II paraesophageal hernia, J. Thorac. Cardiovasc. Surg. 111 (1996) 655–661.
[15] G. Morris-Stiff, A. Hassn, Laparoscopic paraoesophageal hernia repair: fundoplication is not usually indicated, Hernia 2008 (12) (2008) 299–302.
[16] L.A. Mark, A. Okrainec, L.E. Ferri, L.S. Feldman, S. Mayrand, G.M. Fried, Comparison of patient-centered outcomes after laparoscopic Nissen fundoplication for gastroesophageal reflux disease or paraesophageal hernia, Surg. Endosc. 2008 (22) (2008) 343–347.
[17] J.H. Peters, SAGES guidelines for the management of hiatal hernia, Surg. Endosc. 27 (12) (2013 Dec) 4407–4408.

2.2 Lightweight titanium-coated mesh versus standard weight polypropylene mesh in totally extraperitoneal inguinal hernia repair. [Appendix B] [50]

This paper focuses on the outcomes of TEP repair using a standard weight (80 g/m^2) polypropylene monofilament mesh with medium-sized pores (Prolene, Ethicon, Amesforth, The Netherlands) or a lightweight (35 g/m^2) titanium-coated mesh with large pores (TiMesh light, Pfm, Cologne, Germany). The study included 138 patients with unilateral inguinal hernias. The polypropylene group (PP) consisted of 84 patients whereas the titanium-coated group (Ti) consisted of 54 patients. BMI, ASA classification and hernia size were comparable in both patient groups. Postoperative morbidity was similar in both study groups [PP vs. Ti: 9,6% (n=8) vs. 12,6% (n=7), p=0,96]. There was also no difference noted in clinically relevant reported pain at 24 hours post-operatively [PP vs. Ti: 4,8% (n=4) vs. 1,9% (n=1), p=0,34]. At follow-up (mean time: 21,06 months, range: 9-48) there was also no statistically significant difference noted between the two groups regarding clinically relevant pain [PP vs. Ti: 7,8% (n=5) vs. 8,3% (n=3), p=0,92]. There were no differences noted with respect to chronic inguinal pain lasting at least three months postoperatively [PP vs. Ti: 14% (n=9) vs. 5,5% (n=2), p=0,19]. Recurrence rate was also found to be statistically indifferent between the two groups [PP vs. Ti: 1,5% (n=1) vs. 0, p=0,42].

Lightweight Titanium-coated Mesh Versus Standard-Weight Polypropylene Mesh in Totally Extraperitoneal Inguinal Hernia Repair (TEP): A Cohort Analysis

Dimitrios Prassas, MD, Thomas-Marten Rolfs, MD, Nishank Sirothia, MD, and Franz-Josef Schumacher, MD

Purpose: The study objective is to compare the outcomes of laparoscopic to tally extraperitoneal repair using the standard-weight polypropylene mesh or a lightweight titanium-coated mesh.

Methods: A retrospective review was conducted on 138 adult patients with unilateral inguinal hernias, who underwent totally extraperitoneal inguinal hernia repair between 2010 and 2013 using either a standard-weight polypropylene mesh (Prolene mesh, 80 g/m^2) or a lightweight titanium-coated mesh (Ti Mesh light, 35 g/m^2).

Results: There was no difference in reported pain at 24 hours postoperatively. The difference in reported pain at follow-up (mean: 21 mo) was insignificant [PP vs. Ti: 7.8% (n = 5) vs. 8.3% (n = 3), $P = 0.92$], the differences regarding chronic inguinal pain was also insignificant [PP vs. Ti: 14% (n = 9) vs. 5.5% (n = 2), $P = 0.191$], and there was no difference in the development of hernia recurrence [PP vs. Ti: 1.5% (n = 1) vs. 0, $P = 0.42$].

Conclusions: No statistically significant differences of the overall postoperative outcome were observed between the 2 mesh types.

Key Words: inguinal hernia, totally extraperitoneal (TEP) hernia repair, prosthetics, titanized mesh, polypropylene mesh, lightweight titanium-coated mesh

(*Surg Laparosc Endosc Percutan Tech* 2016;26:e113–e116)

Inguinal hernia repair is one of the most common procedures worldwide with > 200,000 operations per year being performed in Germany alone.[1] Tension-free repair with use of a prosthetic mesh in the 1980s has been a major breakthrough, with the laparoscopic techniques further revolutionizing the field.[2] Laparoscopic transabdominal preperitoneal repair, first described in 1990,[3] followed by the introduction of laparoscopic totally extraperitoneal (TEP) repair 1 year later,[4] are 2 well-established minimally invasive approaches with well-documented minimization of postoperative pain, acceleration of patient recovery, and dropping of recurrence rate to 2% to 3%,[5,6] with the choice between the 2 being a matter of personal preference.

Chronic pain following inguinal hernia repair remains, nevertheless, an issue with incidence rates ranging from 0.7% to 43.3%.[7,8] The mesh-induced local inflammatory reaction, followed by a chronic foreign-body fibroblastic response, although of paramount importance for mesh fixation and incorporation in the abdominal wall tissues, can lead to the development of chronic inguinal pain.[9] A plethora of meshes has been engineered, with a steadily growing interest in lightweight, large-pore prosthetics. The benefits of the latter have been well demonstrated in open repair but not clearly in minimally invasive repairs, with the question of the most appropriate mesh still remaining open.[10,11] Moreover, there have been many trials comparing standard-weight polypropylene meshes with titanized meshes, implanted either with open tension-free methods or with laparoscopic transabdominal preperitoneal repair, with the evidence regarding TEP still remaining scarce.[12]

The aim of our study is to compare the outcomes after TEP inguinal hernia repair using a standard-weight prolene mesh or a lightweight titanium-coated mesh, in regard of perioperative morbidity, postoperative pain, chronic inguinal pain occurrence, and hernia recurrence.

MATERIALS AND METHODS

Patient Population and Data Collection

The study retrospectively examined the outcomes of elective TEP inguinal hernia repair in 138 adult patients with unilateral hernias comparing standard-weight polypropylene mesh and lightweight titanium-coated mesh. The operations were conducted between August 2010 and August 2013. Patients with bilateral hernias (n = 27), hernia recurrence (n = 32), patients who received a type of mesh other than those above mentioned (n = 18), patients on whom was conducted a surgical technique other than TEP (n = 14), and cases where the mesh was fixated (n = 11) were excluded from the study. Patient data were collected from our computer-based patients' records database. They were asked to assess the severity of their symptoms on a 10-point Likert scale preoperatively, 24 hours postoperatively, and on follow-up, which was conducted by means of phone interviews. All patients who reported pain or swelling of the groin were offered a clinical examination by means of an outpatient appointment. In addition, patients were also asked about the presence of chronic pain, recurrence, and paresthesias at the area of the operated groin. The main outcome measures included

Received for publication September 24, 2016; accepted October 3, 2016.
From the Department of Surgery, Katholisches Klinikum Oberhausen, Teaching Hospital of the University of Duisburg-Essen, Oberhausen, Germany.
The study was privately funded.
All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its' later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.
The authors declare no conflicts of interest.
Reprints: Dimitrios Prassas, MD, Department of Surgery, Katholisches Klinikum Oberhausen, Teaching Hospital of the University of Duisburg-Essen, Nürnberger Str. 10, 46117 Oberhausen, Germany (e-mail: dimitrisprassas@yahoo.gr).

chronic pain and recurrence. Secondary outcomes were perioperative morbidity and immediate postoperative pain.

Operation and Mesh Types

All cases were operated in our institution by one of 5 experienced surgeons. All procedures were performed under general anesthesia following the principles of TEP repair, with care being taken to avoid any lesions of nerve structures and to position the mesh so that there was adequate coverage of both direct and indirect spaces. The 2 different types of commercially available meshes examined were a 10×15-cm polypropylene monofilament standard-weight ($80\,g/m^2$) mesh with medium pores (Prolene; Ethicon, Amersfoort, The Netherlands) and a 10×15-cm lightweight ($35\,g/m^2$) titanium-coated polypropylene mesh with large pores (TiMesh light; Pfm, Cologne, Germany). The choice of mesh was based on surgeons' personal preference.

Statistics

Standard statistical analysis was performed using Pearson χ^2 test for categorical variables and the Mann-Whitney U test for ordinal data. Statistical significance was set at a level of $P \leq 0.05$. All data were analyzed using the IBM SPSS Statistics 22.0 software.

RESULTS

The study included 138 consecutive patients with unilateral, primary reducible inguinal hernias, who underwent an elective laparoscopic TEP repair, without fixation of the mesh, between August 2010 and August 2013.

Subgroup Comparison

The type of mesh used was either a standard-weight polypropylene mesh (PP group, n = 84) or a lightweight titanized mesh (Ti group, n = 54). Differences between the 2 groups were significant for age (PP vs. Ti in years: 62.7, SD = 15.2 vs. 52.3, SD = 18.8, $P < 0.001$) and sex (PP vs. Ti: 78 males/6 Females vs. 33 males/21 females, $P < 0.001$). BMI, ASA classification, and hernia size were comparable in both groups. The baseline characteristics of the study population are presented in Table 1.

Intraoperative and Immediate Postoperative Findings

All procedures were carried out laparoscopically with no case of conversion to open surgery. Operative time was significantly shorter for the Ti group (operative time in minutes: Ti vs. PP: 34.19, SD = 12.39 vs. 43.3, SD = 16.26, $P = 0.027$). None of the 138 operations had major intraoperative complications. A total of 15 patients (10.8%) developed postoperative complications Postoperative morbidity was similar for both groups (PP vs. Ti: 19.2% vs. 16.2%, $P = 0.96$). Two patients (2.3%) of the PP group experienced postoperative hemorrhage and returned to the OR for hemostasis ($P = 0.25$). One patient belonging to the Ti group (1.8%) suffered a mesh infection that necessitated surgical explantation of the latter ($P = 0.21$). A total of 10 (7.2%) patients, 5 in each group, developed a local seroma that resolved spontaneously, without any interventions required ($P = 0.46$). The overall 30-day mortality was 0%. There were no differences between the 2 groups with respect to clinically relevant pain (4 to 10 on a 10-point Likert scale) at 24 hours postoperatively [PP vs. Ti: 4.8% (n = 4) vs. 1.8% (n = 1), $P = 0.34$] (Table 2).

Follow-up

Complete follow-up information was available for 100 patients (follow-up rate of 72.5%; range, 9 to 48 mo) with a mean follow-up time of 21.06 months (SD = 7.6). Six patients (4.3%) were deceased, 20 (14.5%) could not be contacted, and 12 (8.5%) did not wish to participate in the study. There were no significant differences between the 2 groups (follow-up time in months: Ti vs. PP: 22.31, SD = 7.9 vs. 20.36, SD = 7.4, $P = 0.355$). The number of patients reporting pain of any intensity at follow-up was 14 (21.8%) with polypropylene mesh and 4 (11.1%) with titanium-coated mesh ($P = 0.18$). The difference in reported clinically relevant pain (4 to 10) is also statistically insignificant [Ti vs. PP: 4 (7.4%) vs. 9 (14%), $P = 0.76$]. There were no differences with respect to inguinal pain lasting >3 months [Ti vs. PP: 2 (5%) vs. 9 (14%), $P = 0.19\%$]. The differences regarding pain at rest and on exertion between the groups were also insignificant. There were no statistical differences noted in the development of hernia recurrence between the 2 mesh types [Ti vs. PP: 0 vs. 1 (1.5 %), $P = 0.42$]. All follow-up data are summarized in Table 3.

DISCUSSION

General Considerations

The discrepancy between regional mechanical stability of the abdominal wall tissues and tensile forces applied in vivo is the causative factor in the development of inguinal hernia. Relatively high recurrence rates after primary suture repairs led to the introduction of tension-free mesh repairs, dramatically reducing the risk of recurrence.[13] The ideal prosthetic material should have a tensile strength capable of withstanding the maximum forces exerted on the abdominal wall and, at the same time, approach the elasticity, softness, and compliance of the supported structures. Worldwide, about 20 million prosthetic meshes are estimated to be implanted each year.[14]

TABLE 1. Baseline Characteristics of the Study Population

	All Patients	Polypropylene Mesh	Titanized Mesh	*P*
Age ± SD (y)	58.6 ± 17.5	62.7 ± 15.3	52.3 ± 18.8	< 0.001
Sex (male/female)	111/27	78/6	33/21	< 0.001
ASA [n (%)]				0.43
I	9 (6.5)	5 (6)	4 (7.4)	
II	105 (76.1)	63 (75)	42 (77.8)	
III	23 (16.7)	15 (17.9)	8 (14.8)	
IV	1 (0.7)	1 (1.2)	0	
BMI ± SD (kg/m^2)	26.73 ± 4.9	26.8 ± 4.8	29.6 ± 5	0.83
Preoperative pain ± SD (0: minimum, 10: maximum)	3.01 ± 2.06	2.87 ± 2.24	3.25 ± 1.73	0.3

TABLE 2. Operative Data and Early Postoperative Outcomes

	n (%)		
	Polypropylene Mesh	Titanized Mesh	P
Operative time ± SD (min)	43.4 ± 16.3	34.2 ± 12.4	0.027
Hernia size (cm)			0.39
< 1.5	13 (15)	13 (24.4)	
1.5-3	55 (65.5)	30 (55.6)	
> 3	16 (19)	11 (20.4)	
Postoperative morbidity	8 (9.6)	7 (12.6)	0.96
Postoperative bleeding	2 (2.4)	0	
Dysesthesia	1 (1.2)	1 (1.8)	
Mesh infection	0	1 (1.8)	
Seroma	5 (6)	5 (9)	
Reoperation	9 (2.4)	0	0.25
Postoperative pain (0: minimum, 10: maximum)			
0	21 (2.5)	17 (31.5)	0.45
1-3	57 (69.5)	36 (66.6)	0.46
≥4	4 (4.8)	1 (1.9)	0.34

Synthetic Prosthetic Choices in Hernia Repair

Currently, there are approximately 130 different mesh types commercially available. The basic differences between them are mesh material, weight, and pore size. The most commonly used materials are polypropylene, consisting of polymerized propylene chains, polyethylene terephthalate (PET), a synthetic polyester polymer, expanded polytetrafluoroethylene (ePTFE), and semiabsorbable meshes such as polypropylene-poliglecaprone monofilaments. The additional application of atomic titanium coating has been shown to increase biocompatibility and reduce the shrinkage rate compared with bare polypropylene meshes.[15] Mesh weight refers to the density of the material used and is directly related to the chronic host response, altering the mechanical properties of the mesh. Tensiometry studies have shown that the maximally tolerated tensile strength on polypropylene (80 g/m^2) meshes are much greater than those measured on inguinal fascias in vivo.[16,17] This concept gave birth to another generation of low-weight meshes (≤35 g/m^2).[18] Mesh pore size is another characteristic of decisive importance to the degree of integration to the abdominal wall. Pore size is proportional to the tissue ingrowth and incorporation to the groin tissues. Moreover, large-pore meshes (pore size > 1000 μm) allow the passage of macrophages, in case of infection. An additional titanium coating to the polypropylene meshes has shown in experimental studies an increased biocompatibility with more long-lasting mechanical properties after explantation in comparison to bare polypropylene meshes.[19]

In open inguinal hernia repairs with mesh implantation the use of lightweight, big-pore prosthetics has been shown in several studies to reduce the rate of chronic inguinal pain and foreign body sensation.[20] In laparoscopic repair this effect has not yet been clearly shown.[12]

TABLE 3. Follow-up

	n (%)		
	Polypropylene Mesh	Titanized Mesh	P
Follow-up ± SD (mo)	20.4 ± 7.4	22.3 ± 7.9	0.36
Follow-up	64/84 (76.2)	36/54 (66.6)	0.22
Pain at follow-up			
0	50 (78.1)	32 (88.8)	0.18
1-3	9 (14)	1 (2.8)	0.07
≥4	5 (7.8)	3 (8.3)	0.92
Chronic pain (> 3 mo)	9 (14)	2 (5.5)	0.19
Pain at rest	9 (14)	2 (5.5)	0.19
Pain on exertion	6 (9.3)	2 (5.5)	0.49
Hernia recurrence	1 (1.5)	0	

Study Heterogeneity

Heterogeneity exists between published studies with regard to the laparoscopic surgical method, use of fixation device, and mesh types compared. Our study focuses on occurrence of chronic pain and hernia recurrence in adult patients with unilateral hernias undergoing laparoscopic TEP repair with use of a standard-weight polypropylene mesh or lightweight titanized mesh, without fixation. The exclusion of cases where fixation devices were used increases the quality of study results in relation to postoperative pain, eliminating the effect of intraoperative fixation-associated inguinal nerve lesions.

Outcomes

The Titanized mesh group consists of 54 patients, whereas the polypropylene mesh group consists of 84 patients. The Ti-mesh group consisted of significantly more female and younger patients, whereas polypropylene mesh group consisted of significantly more male patients, explaining the prolonged operative time in this group as the dissection of the spermatic cord structures in male patients is necessary. The previously reported effect of lower postoperative pain scores in patients who received low-weight meshes could not be reproduced in our study, although a slight trend favoring the Ti-mesh group existed. With respect to chronic pain (lasting > 3 mo), we noted a weak statistical trend toward significance also favoring the Ti-mesh group. There were no differences between the 2 mesh groups with respect to clinically relevant pain (4 to 10) after a mean follow-up of 21 months. In the follow-up period, recurrence was seen in 1 patient of the polypropylene group. It seems, at least at follow-up, that there were no significant differences between the 2 meshes compared regarding tissue incorporation and mechanical stability.

Technical Considerations and Use of Mesh Fixation

At this point it must be noted that, regardless of the mesh implanted, care was taken intraoperatively to adequately dissect the preperitoneal space and create an area where the 10 × 15-cm mesh can be deployed in a flat manner, covering all potential hernia rings. Contrary to recent publications that suggest the routine fixation of the mesh,[21,22] the observed recurrence rate was minimal, making the use of fixation devices meaningful in repairs of large hernia defects.

Study Limitations

We recognize the fact that the mean follow-up time of our study might be inadequate as just half of the total recurrences have been shown to manifest by 2 years.[23] Another limitation of the present study is the disproportionate number of female patients between the 2 mesh groups, which, nevertheless, does not affect the comparison

between the subgroups as existing data of regression analyses do not correlate sex to the endpoints of the present study as risk factor.[24,25] Taking into consideration the overall low incidence of chronic pain and hernia recurrence, large-scale, multicenter, randomized studies are needed for solid conclusions to be reached.

CONCLUSIONS

In conclusion, in this observational, single-center study, titanium-coated lightweight meshes for laparoscopic TEP hernia repair showed no short-term or long-term advantages regarding perioperative morbidity, immediate postoperative inguinal pain, chronic inguinal pain, and hernia recurrence, compared with the standard-weight prolene mesh. Randomized, multicenter trials with a longer follow-up period are required to verify the tendencies toward statistical significance observed in the present study.

REFERENCES

1. Jähne J. Surgery of inguinal hernia. *Chirurg*. 2001;72:456–469.
2. Lichtenstein IL, Shulman AG, Amid PK, et al. The tension free hernioplasty. *Am J Surg*. 1989;157:188–193.
3. Schultz L, Graber J, Pietrafitta J, et al. Laser laparoscopic herniorraphy: a clinical trial preliminary results. *J Laparoendosc Surg*. 1990;1:41–45.
4. Dulucq JL. Treatment of inguinal hernia by insertion of a subperitoneal patch under pre-peritoneoscopy. *Chirurgie*. 1992; 118:83–85.
5. Memon MA, Cooper NJ, Memon B, et al. Meta-analysis of randomized clinical trials comparing open and laparoscopic inguinal hernia repair. *Br J Surg*. 2003;90:1479–1492.
6. Simons MP, Aufenacker T, Bay-Nielsen M. European Hernia Society guidelines on the treatment of inguinal hernia in adult patients. *Hernia*. 2009;13:343–403.
7. Inaba T, Okinaga K, Fukushima R, et al. Chronic pain and discomfort after inguinal hernia repair. *Surg Today*. 2012;42: 825–829.
8. Alfieri S, Amid PK, Campanelli G, et al. International guidelines for prevention and management of post-operative chronic pain following inguinal hernia surgery. *Hernia*. 2012; 15:239–249.
9. Klinge U, Conze J, Limberg W, et al. Pathophysiology of the abdominal wall. *Chirurg*. 1996;67:229–323.
10. Sajid MS, Leaver C, Baig MK, et al. Systematic review and meta-analysis of the use of lightweight versus heavyweight mesh in open inguinal hernia repair. *Br J Surg*. 2012;99:29–37.
11. Currie A, Andrew H, Tonsi A, et al. Lightweight versus heavyweight mesh in laparoscopic inguinal hernia repair: a meta-analysis. *Surg Endosc*. 2012;26:2126–2133.
12. Sajid MS, Kalra L, Parampalli U, et al. A systematic review and meta-analysis evaluating the effectiveness of lightweight mesh against heavyweight mesh in influencing the incidence of chronic groin pain following laparoscopic inguinal hernia repair. *Am J Surg*. 2013;205:726–736.
13. Scott NW, McCormack K, Graham P, et al. Open mesh versus non-mesh for repair of femoral and inguinal hernia. *Cochrane Database Syst Rev*. 2002;2002:CD002197. Doi:10.1002/14651858.CD002197.
14. Sanders DL, Kingsnorth AN. Prosthetic mesh materials used in hernia surgery. *Expert Rev Med Devices*. 2012;9:159–179.
15. Scheidbach H, Tannapfel A, Schmidt U. Influence of titanium coating on the biocompatibility of a heavyweight polypropylene mesh. An animal experimental model. *Eur Surg Res*. 2004; 36:313–317.
16. Klosterhalfen B, Junge K, Klinge U. The lightweight and large porous mesh concept for hernia repair. *Expert Rev Med Devices*. 2005;2:103–117.
17. Klosterhalfen B, Klinge U, Schumpelick V. Functional and morphological evaluation of different polypropylene-mesh modifications for abdominal wall repair. *Biomaterials*. 1998;19: 2235–2246.
18. Coda A, Lamberti R, Martorana S. Classification of prosthetics used in hernia repair based on weight and biomaterial. *Hernia*. 2012;16:9–20.
19. Köckerling F, Schug-Pass C. What do we know about titanized polypropylene meshes? An evidence-based review of the literature. *Hernia*. 2014;18:445–457.
20. Burgmans JP, Voorbrood CE, Simmermacher RK. Long-term results of a randomized double-blinded prospective trial of a lightweight (Ultrapro) versus a heavyweight mesh (Prolene) in laparoscopic total extraperitoneal inguinal hernia repair (TULP-trial). *Ann Surg*. 2016;263:862–866.
21. Teng YJ, Pan SM, Liu YL. A meta-analysis of randomized controlled trials of fixation versus nonfixation of mesh in laparoscopic total extraperitoneal inguinal hernia repair. *Surg Endosc*. 2011;25:2849–2858.
22. Koch CA, Greenlee SM, Larson DR, et al. Randomized prospective study of totally extraperitoneal inguinal hernia repair: fixation versus no fixation of mesh. *JSLS*. 2006;10: 457–460.
23. McCormack K, Scott NW, Go PM, et al. EU Hernia Trialists Collaboration. Laparoscopic techniques versus open techniques for inguinal hernia repair. *Cochrane Database Syst Rev*. 2013;2003:CD001785. Doi:10.1002/14651858.CD001785.
24. Patel LY, Lapin B, Gitelis ME, et al. Long-term patterns and predictors of pain following laparoscopic inguinal hernia repair: a patient-centered analysis. *Surg Endosc*. 2016. [Epub ahead of print]. Doi: 10.1007/s00464-016-5207-0.
25. Nienhuijs S, Staal E, Strobbe L, et al. Chronic pain after mesh repair of inguinal hernia: a systematic review. *Am J Surg*. 2007;194:394–400.

2.3 Effect of previous lower abdominal surgery on outcomes following totally extraperitoneal inguinal hernia repair. [Appendix C] [51]

Previous abdominal surgery is generally regarded as a contraindication for TEP. Nevertheless, data regarding this issue is surprisingly limited. The aim of this paper was to investigate the feasibility and safety of TEP repair in patients with history of lower abdominal surgery. The study included 301 consecutive patients with reducible groin hernias who underwent elective TEP repairs. One hundred and thirty-five patients (44,9%) had previously undergone lower abdominal surgery (PS patient group). No difference was noted regarding intra-operative complications between the two groups [nPS vs. PS: 0,6% (n=1) vs. 2,9% (n=4), p=0,11]. Conversion rate was also similar in both groups [nPS vs. PS: 0,6% (n=1) vs. 1,5% (n=2), p=0,44]. Post-operative morbidity was found to be comparable in both groups [nPS vs. PS: 1,2% (n=2) vs. 4,4% (n=6), p=0,08]. Immediate post-operative pain and dysesthesia did not differ significantly between the two study groups. At follow-up (mean time: 20,38 months, range: 3-48) no significant differences with respect to groin pain were noted (nPS vs. PS: 0,72±1,83 vs. 1,26±2,38 p=0,13). Chronic inguinal pain lasting at least three months post-operatively was also insignificantly different between the two groups [nPS vs. PS: 11,9% (n=10) vs. 20% (n=13), p=0,17]. Three recurrences were noted at follow-up in the nPS group compared to a single recurrence noted in the PS group (p=0,44).

Effect of Previous Lower Abdominal Surgery on Outcomes Following Totally Extraperitoneal (TEP) Inguinal Hernia Repair

Dimitrios Prassas, MD,† Argyro Ntolia, MD,* Julia Brosa, MD,* Aristodemos Kounnamas, MD,‡ Thomas-Marten Rolfs, MD,* Franz-Josef Schumacher, MD,* and Andreas Krieg, MD†*

Background: Previous lower abdominal surgery is generally considered as a relative contraindication for laparoscopic totally extraperitoneal (TEP) inguinal hernia repair. Our objective was to investigate the feasibility and safety of TEP repair in patients with a history of lower abdominal surgery.

Materials and Methods: A retrospective analysis of 301 patients with inguinal hernia who underwent elective laparoscopic TEP repair between August 2010 and August 2014 was conducted. One-hundred five patients (34.9%) had previously undergone lower abdominal surgery. The main outcome measures included intraoperative and postoperative morbidity and mortality. Secondary outcomes were immediate postoperative pain, presence of chronic pain at follow-up, and hernia recurrence.

Results: Patient demographics and clinical variables were balanced between the 2 groups, with the exception of age. Intraoperative morbidity was similar between cases without previous lower abdominal surgery (nPS) and cases with history of lower abdominal surgery (PS) [nPS vs. PS: 0.5% (n = 1) vs. 2.8% (n = 3), $P = 0.09$]. Overall 30-day morbidity was found to be significantly higher in the PS patient group [nPS vs. PS: 1.5% (n = 3) vs. 6.6% (n = 7), $P = 0.018$]. Mortality was nil. There were no differences noted between the 2 groups with respect to early postoperative pain and chronic inguinal pain. Complete follow-up information was available for 149 of 301 patients (follow-up rate of 49.5%, range: 3 to 48 mo) with a mean follow-up time of 20.38 months (SD = 7.7). There was no statistically significant difference noted in the recurrence rate between the 2 patient groups at follow-up [nPS vs. PS: 3.2% (n = 3) vs. 1.8% (n = 1), $P = 0.6$].

Conclusions: The present work demonstrates higher incidence of postoperative scrotal hematoma after TEP repair in patients with history of previous lower abdominal surgery. All remaining outcomes of interest were found to be similar between the 2 patient groups. Further trials will be needed to verify our findings.

Key Words: laparoendoscopic hernia repair, inguinal hernia, totally extraperitoneal repair

(*Surg Laparosc Endosc Percutan Tech* 2019;29:267–270)

Received for publication September 22, 2018; accepted December 18, 2018.

From the *Department of Surgery, Katholisches Klinikum Oberhausen, Teaching Hospital of the University of Duisburg-Essen, Oberhausen; †Department of Surgery (A), Heinrich Heine University Duesseldorf, Duesseldorf; and ‡Department of Surgery, Alexianer Hospital Krefeld, Krefeld, Germany.

All procedures performed in this study involving human participants were in accordance with the ethical standards of the Institutional and/or National Research Committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was approved by the ethics committee of our institution. Informed consent was obtained from all individual participants included in the study.

The study was privately funded. The authors declare no conflicts of interest.

Reprints: Dimitrios Prassas, MD, Moorenstrasse 5, 46225 Düsseldorf, Germany (e-mail: dimitrios.prassas@med.uni-duesseldorf.de).

Inguinal hernia repair is one of the most common surgical procedures worldwide with > 200,000 operations per year being performed in Germany alone.[1] The introduction of laparoscopy revolutionized the field of hernia surgery in the early 1990s with the development of transabdominal preperitoneal approach (TAPP).[2] This technique paved the way for the laparoscopic totally extraperitoneal (TEP) repair one year later,[3] an approach reaping maximum benefits of minimally invasive inguinal hernia surgery. However, the latter requires the dissection of the preperitoneal space, whose access may be particularly challenging when scar tissue from previous lower abdominal surgery is encountered. In general, patients with groin hernias who have previously undergone lower abdominal surgery are not considered as the ideal candidates for TEP repair. Nevertheless, data with regard to the feasibility and safety of TEP repair after previous lower abdominal surgery is limited.[4–10] The aim of this study is to compare the outcomes after TEP repair between patients with and without previous lower abdominal surgery with regard of intraoperative and perioperative morbidity, postoperative pain, chronic inguinal pain occurrence, and hernia recurrence.

MATERIALS AND METHODS

Patient Population and Data Collection

We retrospectively analyzed the outcomes of elective laparoscopic TEP repair in 301 adult patients with groin hernias in relation with previous lower abdominal surgery. The operations were conducted in our institution between August 2010 and August 2014. Patients who presented with an incarcerated groin hernia (n = 8), patients on who a surgical technique other than TEP (n = 14) was conducted and cases where the mesh was fixated (n = 11) were excluded from the analysis. Patient data were collected from our computer-based patients' records database. All patients were asked to subjectively assess the severity of groin pain in a 10-point Visual Analog Scale (VAS) 24 hours postoperatively and on follow-up. Further enquiries were also made with regard to paresthesia, presence of chronic groin pain and hernia recurrence. Follow-up was conducted by means of phone interviews. Patients who reported pain or swelling were clinically examined by one of the operating surgeons, for further assessment and/or treatment. The main outcome of interest was intraoperative and postoperative morbidity and mortality. Secondary outcomes were immediate postoperative pain, presence of chronic pain at follow-up and hernia recurrence. Patients with history of open inguinal hernia repair, as well as history of laparoscopic

appendectomy were not considered as relevant to the clinical question of the present work and were not included in the PS group.

Surgical Technique

Our surgical approach of choice is TEP, regardless of previous lower abdominal surgery. All cases were operated in our institution by 5 surgeons with expertise in advanced laparoscopic surgery following the principles of TEP repair in 3 trocar technique. The preperitoneal space is expanded with the insufflation of a spherical-shaped balloon dilatator, followed by blunt dissection using forceps and sharp dissection using scissors, when necessary. Three different types of prosthetic mesh were implanted. In the majority of cases (n = 196) a standard weight Polypropylene mesh (Prolene; Ethicon, Amersfoort, The Netherlands) was used, followed by a lightweight titanium-coated polypropylene mesh (n = 91) (TiMesh light; pfm Medical, Cologne, Germany). In the remaining cases (n = 14), a partially absorbable lightweight mesh was used (ULTRAPRO; Ethicon). The choice of implanted mesh was based on surgeons' personal preference.

Statistics

Descriptive statistics were calculated for the patients' data and were presented as mean ± SD. Continuous variables were compared using the Students t test. Categorical variables were compared using the Pearson χ^2 test or Fischer exact test where appropriate. Statistical significance was set at a level of $P \leq 0.05$. All data were analyzed using the IBM SPSS Statistics software for Windows and Mac (version 24.0; SPSS Inc.).

RESULTS

Patient Characteristics and Subgroup Comparison

The study included 301 consecutive patients (265 male, 36 female) with reducible groin hernias, who underwent an elective laparoscopic TEP repair, without fixation of the mesh. The operations were conducted between August 2010 and August 2014. One-hundred five patients (34.9%) had previously undergone lower abdominal surgery. Table 1 lists the different types of previously performed relevant surgical interventions. Differences between the 2 groups (no previous surgery group: nPS and previous surgery group: PS) were significant for age (nPS vs. PS in years: 55.7, SD = 18.9 vs. 62.9; SD = 15.4; $P = 0.001$). Sex, body mass index, ASA classification and hernia size were comparable with both groups. The baseline characteristics of the study population are presented in Table 2.

TABLE 1. Type of Previous Lower Abdominal Surgery

Procedure	n (%)
Open appendectomy	35 (33.3)
Laparoscopic TEP	7 (7)
Laparoscopic TAPP	2 (1.9)
Open ovarectomy	2 (1.9)
Open colectomy	9 (8.5)
Open prostatectomy	3 (2.8)
Laparoscopic prostatectomy	6 (5.7)
Robotic prostatectomy	4 (4)
Open aortic aneurysm repair	1 (0.9)
Open hysterectomy	4 (4)
Laparoscopic hysterectomy	1 (0.9)
C-section	5 (4.7)
Laparoscopic adnexectomy	1 (0.9)
Multiple previous surgeries	25 (23.8)

TAPP indicates transabdominal preperitoneal approach; TEP, totally extraperitoneal.

TABLE 2. Baseline Characteristics of the Study Population

	All Cases (N = 301)	No Previous Surgery Group (N = 196)	Previous Surgery Group (N = 105)	P
Age ± SD (y)	58.2 ± 18.1	55.73 ± 18.9	62.9 ± 15.4	0.001
Sex (male/female)	165/36	162/34	83/22	0.5
BMI ± SD (kg/m^2)	26.3 ± 4.4	26.2 ± 4	26.6 ± 5	0.5
ASA [n (%)]				
I	24 (8)	18 (9.2)	6 (5.7)	0.29
II	247 (82.1)	158 (80.6)	89 (84.8)	0.37
III	27 (9)	18 (9.2)	9 (8.6)	0.86
IV	3 (0.1)	2 (1.0)	1 (1.0)	0.95
Hernia ring size (cm)				
< 1.5	87 (29)	57 (29.1)	30 (28.6)	0.92
1.5-3	161 (53.5)	102 (52)	59 (56.2)	0.49
> 3	53 (17.6)	37 (18.9)	16 (15.2)	0.43

BMI indicates body mass index.

Intraoperative Data

No significant difference was noted with regard to operative time between the 2 groups (nPS vs. PS in minutes: 41, SD = 17.8 vs. 43.2; SD = 16.7; $P = 0.3$). Further comparison between the subgroups of unilateral and bilateral hernias also failed to reveal any significant difference. The intraoperative complication rate was similar for both study groups and was exclusively related to bleeding due to injury of the inferior epigastric artery in all cases [nPS vs. PS: 0.5% (n = 1) vs. 2.8% (n = 3), $P = 0.09$]. Two cases in the PS group were converted, one to open anterior approach due to hemorrhage and the remaining one to laparoscopic TAPP repair due to wide violation of the peritoneal envelope and difficulty in developing the operative field. One case in the nPS group was converted to an anterior approach due to hemorrhage [nPS vs. PS: 0.5% (n = 1) vs. 1.9% (n = 2), $P = 0.2$] (Table 3).

Early Postoperative Outcome

Postoperative morbidity was found to be significantly higher in the PS patient group [nPS vs. PS: 1.5% (n = 3) vs. 6.6% (n = 7), $P = 0.08$]. Postoperative clinically significant scrotal hematoma developed in 0.5% (n = 1) of the patients in the nPS group and in 4.7% (n = 5) of the patients in the PS group ($P = 0.01$). With the exception of the patient belonging to the nPS group who returned to the operation room for

TABLE 3. Intraoperative Data

	No Previous Surgery Group (N = 196)	Previous Surgery Group (N = 105)	P
Operation time ± SD (min)	41 ± 17.8	43.2 ± 16.7	0.3
Intraoperative complications	1 (0.5)	3 (2.8)	0.09
Conversion	1 (0.5)	2 (1.9)	0.2

TABLE 4. Postoperative Outcome

	No Previous Surgery Group (N = 196)	Previous Surgery Group (N = 105)	P
Overall 30-day morbidity	3 (1.5)	7 (6.6)	0.018
Scrotal hematoma	1 (0.5)	5 (4.7)	0.012
Inguinal dysesthesia	2 (0.1)	1 (0.9)	0.9
Mesh infection	0	1 (0.9)	0.3
Return to the operation room	1 (0.5)	1 (0.9)	0.6
30-d mortality	0	0	—
Pain intensity at 24 h postoperatively (VAS 0-10) ± SD	1.3 ± 1.2	1.5 ± 1.4	0.1
Pain intensity at follow-up (VAS 0-10) ± SD	0.8 ± 1.9	1.2 ± 2.3	0.3
Chronic pain (> 3 mo) [n/N (%)]	12/88 (13.6)	11/54 (20.3)	0.3
Hernia recurrence	3/93 (3.2)	1/56 (1.8)	0.6

VAS indicates Visual Analog Scale.

hemostasis, all other cases were treated conservatively. Postoperative groin dysesthesia was noted in 0.1% (n = 2) of the patients in the nPS group and in 0.9% (n = 1) of the patients belonging to the PS group ($P = 0.9$). One patient belonging to the PS group (0.9%) suffered a mesh infection that necessitated surgical explantation of the latter. The overall 30-day mortality was nil. Pain intensity at 24 hours postoperatively was not found to be significantly higher in cases with history of previous lower abdominal surgery (nPS vs. PS: 1.3, SD = 1.21 vs. 1.5; SD = 1.42; $P = 0.1$).

Follow-up

Complete follow-up information was available for 149 of 301 patients (follow-up rate of 49.5%, range 3 to 48 mo) with a mean follow-up time of 20.38 months (SD = 7.7). There were no differences between the 2 groups with respect to groin pain at follow-up (nPS vs. PS: 0.8, SD = 1.9 vs. 1.2; SD = 2.3; $P = 0.3$). No significant difference was noted with regard to the number of patients complaining about pain lasting > 3 months [nPS vs. PS: 13.6% (n = 12) vs. 20.3% (n = 11); $P = 0.3$]. There was no difference noted in the recurrence rate between the 2 patient groups at follow-up [nPS vs. PS: 3.2% (n = 3) vs. 1.8% (n = 1); $P = 0.6$]. An overview of the early postoperative and long-term outcome is presented in Table 4.

DISCUSSION

The evolution of minimally invasive repair of inguinal hernias began almost 3 decades ago as the revolution of laparoscopy appeared. The first laparoscopic inguinal hernia repair was described in 1990 and involved placement of a simple mesh plug in the hernia ring.[11] Today, the most common laparoscopic approaches are TAPP and TEP repair. The latter demonstrates advantages over the former in terms of intraperitoneal complications and postoperative pain, at the cost of a steep learning curve, with the European guidelines suggesting a range between 50 and 100 procedures.[12] Complete dissection of the preperitoneal space without violation of the preperitoneal envelope's integrity and the unequivocal identification of key landmarks such as the pubic bone, cord structures, and inferior epigastric vessels is of paramount importance for a safe and successful TEP repair. Dissection of the myopectineal orifice in patients with prior lower abdominal surgery can be challenging because of the associated adhesions in the preperitoneal space. In general, previous lower abdominal surgery is regarded by many surgeons as a relative contraindication to TEP repair; a belief based more on personal experience as published data on this subject is scarce.

In our institution, inability to tolerate general anesthesia is considered to be the only absolute contraindication for TEP repair. The majority of our patients underwent laparoscopic TEP repair regardless of the presence of previous lower abdominal surgery. In all patients the spherical balloon dissector was used to gain access to the preperitoneal space. In cases with significant adhesions, gentle and meticulous dissection must be undertaken minimizing the use of electric cauterization, particularly during lateral dissection to avoid nerve injuries. In the event of peritoneal tear and subsequent pneumoperitoneum, we insert a Veress needle through the paraumbilical incision to reexpand the preperitoneal space. We advise the routine preoperative placement of a Foley catheter in all patients. Especially in patients with previous surgery, the bladder should be completely empty to maximize operative field exposure and minimize the risk of complex bladder injury. In the present study, no major intraoperative complications such as visceral injury, femoral vessel injury, and/or lesions of the vas deferens were noted. The small number of complications noted was exclusively related to bleeding due to injury of the inferior epigastric artery. Hemostasis was achieved in the majority of the cases with the use of clips. Extended violation of the preperitoneal envelope necessitating conversion to laparoscopic TAPP repair was noted in only 1 case. Early postoperative morbidity was found to be significantly higher in the PS group. Subgroup analysis of postoperative morbidity revealed significant differences exclusively related to postoperative scrotal hematoma formation. There were no differences noted between the 2 groups with respect to early postoperative pain and chronic inguinal pain. The rate of hernia recurrence did not differ between the 2 groups at follow-up. The major limitation of the present work is its retrospective nature and lack of randomization. We also recognize the fact that the follow-up rate of our study is relatively low.

CONCLUSIONS

With the exception of a higher rate of scrotal hematomas in the PS group, laparoscopic TEP repair seems to be a safe and feasible approach in patients with inguinal hernia providing similar outcome between patients with and without history of previous lower abdominal surgery. Larger scale trials will be needed to verify our findings.

REFERENCES

1. Jähne J. Surgery of inguinal hernia. *Chirurg*. 2001;72:456–469.
2. Schultz L, Graber J, Pietrafitta J, et al. Laser laparoscopic herniorraphy: a clinical trial preliminary results. *J Laparoendosc Surg*. 1990;1:41–45.
3. Dulucq J. Treatment of inguinal hernia by insertion of a subperitoneal patch under preperitoneoscopy. *Chirurgie*. 1992;118:83–85.
4. Zuiki T, Ohki J, Ochi M, et al. Laparoscopic totally extraperitoneal (TEP) inguinal hernia repair in patients with previous lower abdominal surgery. *Surg Endosc*. 2018. Doi: 10.1007/s00464-018-6223-z. [Epub ahead of print].

5. Ramshaw B, Tucker J, Duncan T, et al. The effect of previous lower abdominal surgery on performing the total extraperitoneal approach to laparoscopic herniorrhaphy. *Am Surg*. 1996;62:292–294.
6. Paterson H, Casey J, Nixon S. Totally extraperitoneal laparoscopic hernia repair in patients with previous lower abdominal surgery. *Hernia*. 2005;9:228–230.
7. Dulucq J, Wintringer P, Mahajna A. Totally extraperitoneal (TEP) hernia repair after radical prostatectomy or previous lower abdominal surgery: is it safe? A prospective study. *Surg Endosc*. 2006;20:473–476.
8. Al-Sahaf O, Al-Azawi D, Fauzi M, et al. Totally extraperitoneal laparoscopic inguinal hernia repair is a safe option in patients with previous lower abdominal surgery. *J Laparoendosc Adv Surg Tech A*. 2008;18:353–356.
9. Chung S, Huang C, Chueh S, et al. Feasibility and safety of total extraperitoneal inguinal hernia repair after previous lower abdominal surgery: a case-control study. *Surg Endosc*. 2011;25:3353–3356.
10. Elshof J, Keus F, Burgmans J, et al. Feasibility of right-sided total extraperitoneal procedure for inguinal hernia repair after appendectomy: a prospective cohort study. *Surg Endosc*. 2009;23:1754–1758.
11. Neumayer L, Giobbie-Hurder A, Jonasson O, et al. Open mesh versus laparoscopic mesh repair of inguinal hernia. *N Engl J Med*. 2004;350:1819–1827.
12. Simons M, Aufenacker T, Bay-Nielsen M, et al. European hernia society guidelines on the treatment of inguinal hernia in adult patients. *Hernia*. 2009;13:343–403.

2.4 Meta-analysis of totally extraperitoneal (TEP) inguinal hernia repair in patients with previous lower abdominal surgery. [Appendix D] [52]

In order to investigate whether the findings of the previous paper C can be generalized on a broader, international population, a Meta-analysis of studies was conducted comparing the feasibility and safety of laparoscopic TEP repair between patients with (PS) and without (NS) history of lower abdominal surgery. A total of seven comparative studies including 1675 cases (PS: 326, NS: 1331) were analyzed. The PS group was found to have a higher rate of intraoperative complications: {OR=2,85, 95%CI [1,28-6,8]; p=0,02; 7 studies, I^2=33%}, as well as a higher rate of post-operative morbidity {OR=2,14, 95% CI [1,28-3,58]; p=0,004; 5 studies, I^2=0%}.

Conversion rate was found to be higher in the PS group {OR=6,41, 95%CI [3,27-12,45]; p=0,001; 7 studies, I^2=0%}. Peritoneal tears were also found to be significantly more frequent in cases with previous surgery {OR=1,79, 95%CI [1,16-2,76]; p=0,009; 6 studies, I^2=0%}, Post-operative seroma rate was found to be higher in the previous surgery patient group {OR=2,44, 95%CI [1,04-5,74]; p=0,04; 3 studies, I^2=0%}.

Operative time was higher for the PS group {OR=2,85, 95%CI [1,28-6,8]; p=0,02; 7 studies, I^2=33%}. The issue of chronic groin pain was addressed in four studies. Meta-analysis of the results failed to demonstrate any significant differences between the two study groups.

In total, one single recurrence was reported in the NS patient group.

Systematic review

Meta-analysis of totally extraperitoneal inguinal hernia repair in patients with previous lower abdominal surgery

D. Prassas[1], T.-M. Rolfs[2], W.-T. Knoefel[1] and A. Krieg[1]

[1]Department of Surgery (A), Heinrich-Heine-University and University Hospital Düsseldorf, Düsseldorf, and [2]Department of General Surgery, Katholisches Klinikum Oberhausen, Oberhausen, Germany

Correspondence to: Dr D. Prassas, Department of Surgery (A), Heinrich-Heine-University and University Hospital Duesseldorf, Moorenstrasse 5, 40225 Düsseldorf, Germany (e-mail: dimitrios.prassas@med.uni-duesseldorf.de)

Background: Previous lower abdominal surgery is considered a relative contraindication to laparoscopic totally extraperitoneal (TEP) inguinal hernia repair. This was a meta-analysis of studies comparing the feasibility and safety of TEP repair between patients with (PS), and without (NS) a history of lower abdominal surgery.

Methods: A systematic literature search was undertaken for studies comparing the outcome of TEP inguinal hernia repair in patients with, and without previous lower abdominal surgery. Data on postoperative outcomes were extracted and compared by meta-analysis. Odds ratios (ORs) and mean differences with 95 per cent confidence intervals were calculated.

Results: Seven comparative cohort studies were identified, involving a total of 1657 procedures (PS 326, NS 1331). There was a statistically significant difference between PS and NS favouring the NS group with regard to both primary outcomes: intraoperative morbidity (OR 2·85, 95 per cent c.i. 1·19 to 6·80; $P = 0·02$; 7 studies; $I^2 = 33$ per cent), and postoperative morbidity in the multiport subgroup (OR 2·14, 1·28 to 3·58; $P = 0·004$; 5 studies; $I^2 = 0$ per cent). For the secondary endpoints conversion rate, peritoneal tears, major intraoperative bleeding, postoperative haematoseroma and delay in return to normal activities, there was a statistically significant difference favouring the NS group.

Conclusion: This study suggests that patients with previous lower abdominal surgery who need hernia repair get less benefit from TEP repair than those with no history of surgery.

Paper accepted 22 January 2019

Published online 26 March 2019 in Wiley Online Library (www.bjs.co.uk). **DOI:** 10.1002/bjs.11140

Introduction

Inguinal hernia repair is one of the most common surgical interventions, with more than 200 000 operations being performed each year in Germany alone[1]. The laparoscopic approach, introduced in the early 1990s, laid the foundation for totally extraperitoneal (TEP) repair. Since its inception in 1992[2], TEP repair has become one of the most popular approaches worldwide, with well documented short- and long-term outcomes[3]. Previous lower abdominal surgery is often considered a relative contraindication to TEP repair, as access to the preperitoneal space may be challenging when scar tissue from previous interventions is encountered. Nonetheless, the feasibility and safety of TEP repair in patients with a history of lower abdominal surgery remains inconclusive[4–16]. The aim of this study was to perform a meta-analysis of trials comparing the feasibility and safety of TEP inguinal hernia repair in patients with (PS, previous surgery group) and without (NS, no previous surgery group) a history of lower abdominal surgery.

Methods

This systematic meta-analysis was conducted according to the PRISMA statement[17].

Eligibility criteria

All studies comparing the outcome of TEP in patients with, and without previous lower abdominal surgery were considered for inclusion, regardless of size or number of study arms. To be included in the analysis, studies had to report on at least one of the following outcomes: intraoperative morbidity, perioperative morbidity, duration of surgery conversion rate, rate of postoperative haematoseroma,

chronic pain, peritoneal tears, hospital stay, delay in return to normal activities and recurrence rate. Non-comparative studies were excluded.

Search strategy

A systematic review was undertaken independently by two authors in Scopus, MEDLINE, and the Cochrane CENTRAL trials register. No language restrictions were applied. Articles published before 2000 were not included. Selected papers were screened by both reviewers for eligibility; discrepancies were resolved by consensus and a third author was consulted when necessary. The search was performed on 1 July 2018. A combination of the following Medical Subject Headings was used for the search: 'total extraperitoneal inguinal hernia repair', 'TEP', 'laparoscopic hernioplasty' combined with 'previous surgery' or 'lower abdominal surgery'.

Data extraction and outcome measures

A self-designed data extraction form was used to extract data of interest independently and blindly from papers meeting the inclusion criteria.

The primary outcomes of interest were intraoperative and postoperative morbidity. Secondary outcomes included: conversion rate, peritoneal tears, major intraoperative bleeding, rate of postoperative haematoseroma, chronic pain, duration of surgery, duration of hospital stay, delay in return to normal activities and recurrence rate. Baseline study characteristics recorded were: year of publication, study type, study origin, study duration, type of procedure investigated (multiport or single port), sample size, age, sex, BMI, type of previous lower abdominal surgery included in the study group, number of surgeons involved and surgical skill level, and type and duration of follow-up.

Quality assessment

The quality of included studies was assessed independently by two authors using the Newcastle–Ottawa Scale[18]. It consists of seven items assessing patient population and selection, study comparability, follow-up and outcome of interest. The maximum total score is nine stars, and the quality of each paper is graded as level 1/low quality (0–5 stars) or level 2/high quality (6–9 stars). The assessors were not blinded to study authors. The methodological quality of the present meta-analysis was ranked as high after implementation of the AMSTAR 2 appraisal tool for systematic reviews that include randomized or non-randomized studies of healthcare interventions[19].

Statistical analysis

Pairwise meta-analyses were conducted. For each outcome of interest, summary estimates of treatment effect were calculated with 95 per cent confidence intervals. The odds ratio (OR) was chosen as effect measure for dichotomous endpoints, and standardized mean difference (MD) for continuous outcomes. The method described by Hozo and colleagues[20] was implemented to calculate mean(s.d.) values when only median and range were reported. Heterogeneity between studies was assessed by means of the I^2 index. Values of 50 per cent or more were regarded as markers of substantial heterogeneity. I^2 values above 75 per cent were regarded as markers of high heterogeneity. Summary estimates were calculated by a fixed-effect method if there was low or moderate heterogeneity (I^2 below 50 per cent). Where two study arms were combined, mean(s.d.) values were extracted and a common value was calculated using methods described in the *Cochrane Handbook for Systematic Reviews of Interventions*[21]. All meta-analyses were conducted in RevMan software version 5.3 (The Nordic Cochrane Centre, Copenhagen, Denmark).

Results

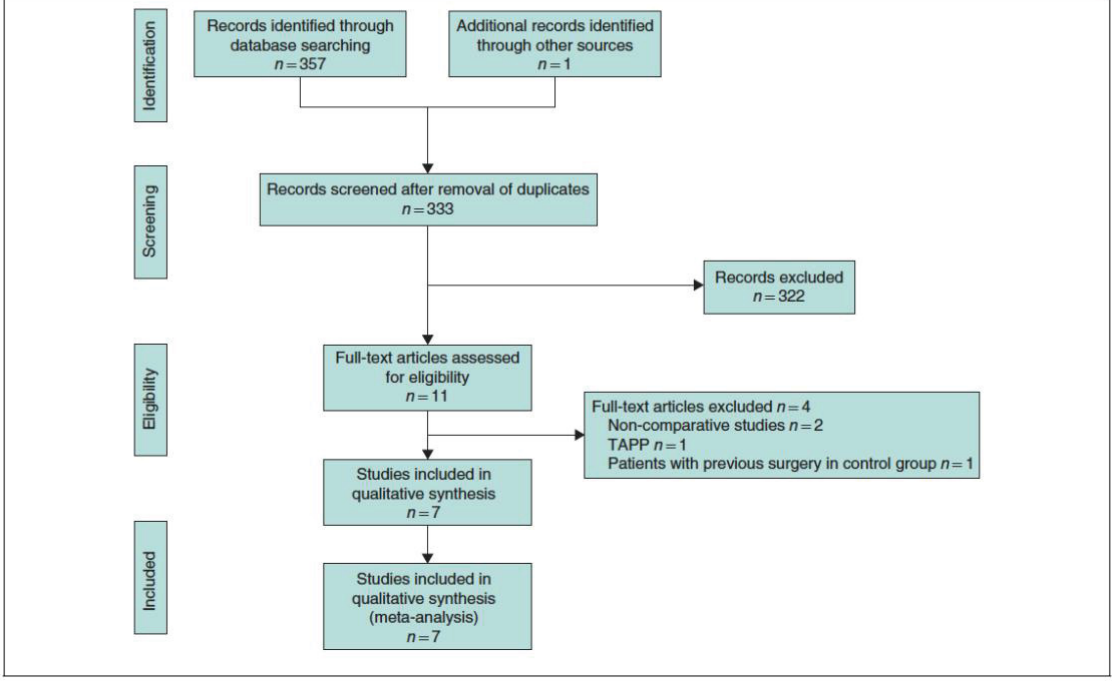
Study selection and characteristics

The electronic database search identified 333 studies, after exclusion of 24 duplicates (*Fig. 1*). Of 11 full-text articles assessed for eligibility, seven studies[4,7–11,13] were included in the qualitative and quantitative data synthesis, involving a total of 1657 hernia repairs (PS 326, NS 1331). Studies excluded after full-text review are summarized in *Table S1* (supporting information).

The literature search revealed no relevant RCTs. All studies were either prospective or retrospective comparative cohort studies. Three[7,10,13] of seven studies stated clearly that hernia incarceration was an exclusion criterion. In another study[8], it was stated that a single case of incarceration was included. The remaining three studies did not provide any data concerning whether the hernia was reducible. With the exception of one study[13] in which single-port TEP repair was performed, all remaining studies used the multiport approach.

Regarding the type of previous surgery, three studies[4,7,8] included all types of lower abdominal surgery, one other study[9] included all types of surgery except previous inguinal hernia repair, one[13] included all types of previous surgery apart from radical prostatectomy, and the remaining two studies included only patients with previous open appendicectomy[10] or radical prostatectomy[11] respectively. Mean follow-up ranged from 1·5 to 25 months (*Table 1*).

Fig. 1 PRISMA diagram showing selection of articles for review



TAPP, transabdominal preperitoneal.

Subgroup analysis

A subgroup analysis was undertaken based on the numbers of ports used to perform TEP hernia repair (multiport or single port) to explore heterogeneity of the results, where appropriate.

Study quality and risk of bias

The quality of all included cohort studies was level 2 (6–9 stars) on the Newcastle–Ottawa Scale[18]. The main limitations arose from the non-randomized nature of the studies. Moreover, even though the reported outcomes of interest were straightforward, the exact definition of outcomes within the included studies was relatively poor.

Primary outcomes

Intraoperative morbidity

All seven included studies reported data on intraoperative complications. A statistically significant difference was noted favouring the NS group (OR 2·85, 95 per cent c.i. 1·19 to 6·80; $P = 0·02$; $I^2 = 33$ per cent) (*Fig. 2*).

Postoperative morbidity

Six studies reported data on postoperative complications. Meta-analysis of the pooled data showed no significant difference between the two study groups (OR 1·49, 95 per cent c.i. 0·97 to 2·29; $P = 0·07$; $I^2 = 35$ per cent). Subgroup analysis of multiport and single-port techniques showed a significant difference favouring the NS group when multiport TEP repair was used (OR 2·14, 1·28 to 3·58; $P = 0·004$; 5 studies; $I^2 = 0$ per cent) (*Fig. 3*).

Secondary outcomes

Major intraoperative bleeding

Data from all seven studies were pooled. A statistically significant difference favouring the NS group was found (OR 2·72, 95 per cent c.i. 1·08 to 6·58; $P = 0·03$; $I^2 = 34$ per cent) (*Fig. S1*, supporting information).

Table 1 Study characteristics

	Elshof *et al.*[10]	Wakasugi *et al.*[13]	Zuiki *et al.*[4]	Chung *et al.*[9]	Le Page *et al.*[11]	Al-Sahaf *et al.*[8]	Dulucq *et al.*[7]
Study type	Prospective cohort	Retrospective cohort	Retrospective cohort	Prospective cohort	Prospective cohort	Retrospective cohort	Prospective cohort
City/Country	Utrecht, the Netherlands	Osaka, Japan	Juki, Japan	Taipei, Taiwan	Sydney, Australia	Dublin, Ireland	Bordeaux, France
Time interval	Jan 2005 to Feb 2007	Jan 2012 to Dec 2015	2006 to 2016	Jan 2008 to Dec 2010	Dec 2004 to Dec 2011	Jan 2001 to Jul 2005	Sep 2003 to Dec 2004
No. of patients	NS 421 PS 41	NS 266 PS 84	NS 229 PS 84	NS 46 PS 23	NS 102 PS 52	NS 90 PS 17	NS 177 PS 25
Age (years)*	NS 54(13·8) PS 56(12·7)	NS 66(12) PS 71(10)	65(16)	NS 55(13·2) PS 56·1(13·5)	NS 69·7(2·5) PS 67·8(5)	55(10·5)	61(16)
Sex ratio (M:F)	NS 407:14 PS 38:3	NS 237:29 PS 71:13	281:32	NS 40:6 PS 20:3	NS 102:0 PS 50:0	106:1	166:36
BMI (kg/m^2)*	NS 24·7(2·9) PS 24·5(3·1)	NS 23(3) PS 22(2)	–	NS 23·4(3·4) PS 23·3(3·2)	–	–	–
No. of surgeons	3	–	–	1	1	1	1
Surgical skill level	Each surgeon >250 procedures	–	–	> 500 TEP and TAPP repairs	TEP repair since early 1990s	Consultant	Consultant
No. of ports	Multiport	Single port	Multiport	Multiport	Multiport	Multiport	Multiport
Duration of surgery (min)*	–	NS 95(25) (unilateral) PS 96(27) (unilateral)	–	NS 72·2(26·4) PS 77·7(35·3)	NS 54(14·3) PS 70(29·3)	NS 29 PS 39·5	NS 15·8(6) PS 23·7(4·5)
Type of previous operations included	Open appendicectomy	Any, apart from radical prostatectomy	Any	Any, apart from hernia repair	Radical prostatectomy	Any	Any
Duration of follow-up (months)*	1·5	NS 25(14) PS 20(13)	–	12	NS 15(5) PS 23(17)	12	8(4)
Type of follow-up	Clinical	Telephone + clinical	–	Clinical	Telephone + questionnaire	–	–

*Values are mean(s.d.). NS, no history of abdominal surgery; PS, previous abdominal surgery; TEP, totally extraperitoneal; TAPP, transabdominal preperitoneal.

Peritoneal tear

Six studies reported on intraoperative tear of the peritoneum. Meta-analysis of pooled data revealed a significant difference in favour of the NS group (OR 1·79, 95 per cent c.i. 1·16 to 2·76; $P = 0·009$; $I^2 = 0$ per cent) (*Fig. S2*, supporting information).

Conversion rate

Data from all included studies were pooled. The meta-analysis showed a significant difference in conversion rate favouring the NS group (OR 6·41, 95 per cent c.i. 3·27 to 12·55; $P < 0·001$; $I^2 = 0$ per cent) (*Fig. S3*, supporting information). These procedures were converted to either open anterior hernia repair or transabdominal preperitoneal (TAPP) repair. The NS group had 12 conversions to open anterior repair and two to TAPP repair, whereas the PS group had 12 conversions to open repair and ten to TAPP repair.

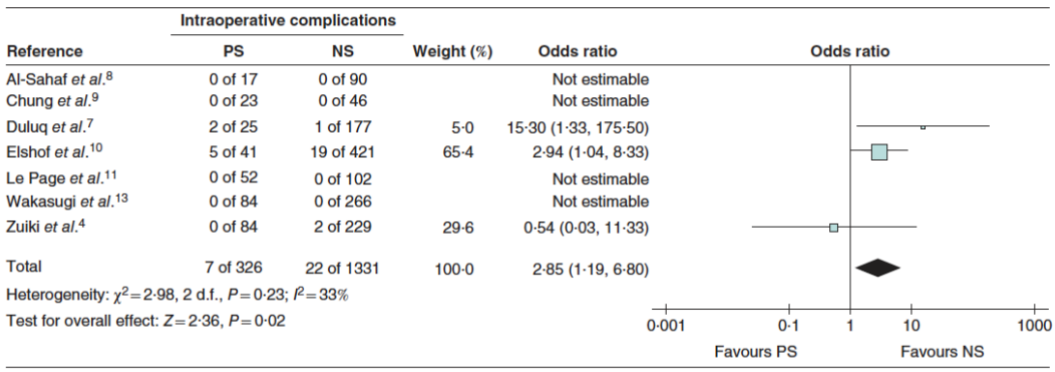
Postoperative haematoseroma

The rate of postoperative haematoseromas was reported in four studies. Meta-analysis of pooled data failed to show any difference between the two study groups. Subgroup analysis of multiport and single-port techniques revealed a significantly lower haematoseroma rate favouring no previous surgery in the multiport subgroup (OR 2·44, 95 per cent c.i. 1·04 to 5·74; $P = 0·04$; 3 studies; $I^2 = 0$ per cent) (*Fig. S4*, supporting information).

Chronic groin pain

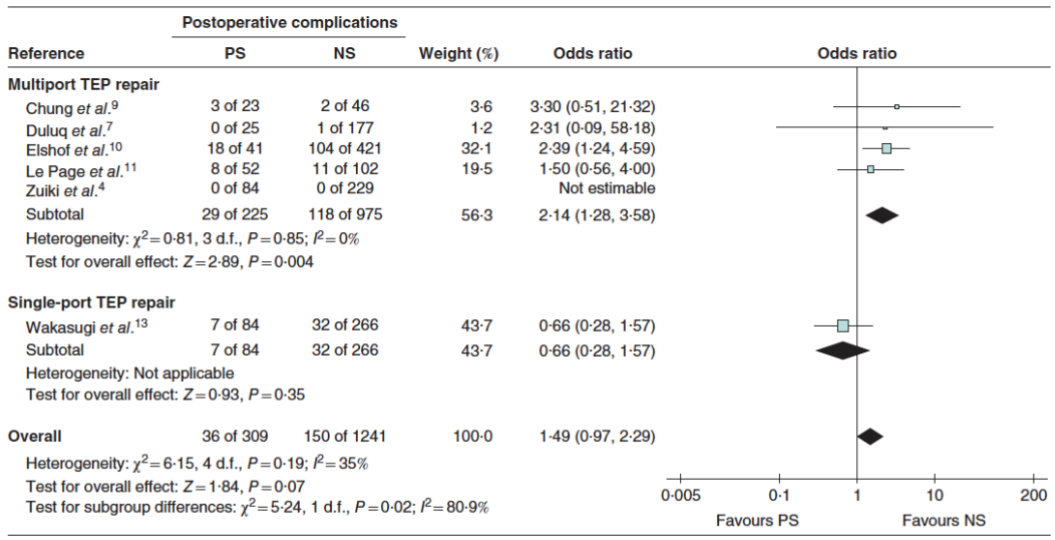
The issue of chronic groin pain was addressed in four studies. Meta-analysis of these results failed to show any differences between the two groups (OR 1·31, 95 per cent c.i. 0·70 to 2·46; $P = 0·40$; $I^2 = 13$ per cent) (*Fig. S5*, supporting information).

Fig. 2 Forest plot comparing rate of intraoperative complications during laparoscopic totally extraperitoneal inguinal hernia repair in patients with *versus* without a history of lower abdominal surgery



Odds ratios are shown with 95 per cent confidence intervals. A Mantel–Haenszel fixed-effect model was used for meta-analysis. PS, previous surgery; NS, no previous surgery.

Fig. 3 Forest plot comparing postoperative morbidity rates after laparoscopic totally extraperitoneal inguinal hernia repair in patients with *versus* without a history of lower abdominal surgery



Odds ratios are shown with 95 per cent confidence intervals. A Mantel–Haenszel fixed-effect model was used for meta-analysis. PS, previous surgery; NS, no previous surgery; TEP, totally extraperitoneal.

Hernia recurrence

Data from six studies including 1264 patients were pooled. Only a single hernia recurrence was reported, in a patient without previous abdominal surgery ($P = 0{\cdot}6$)[11].

Duration of surgery

Duration of surgery was reported in five studies[7–9,11,13]. Data were not pooled owing to high statistical heterogeneity ($I^2 = 90$ per cent). In all four studies, operations took longer in the PS group, with mean(s.d.) values ranging from 23·7(4·5) to 96(27) min, compared with 15·8(6) to 95(25) min in the NS group (*Table 1*).

Duration of hospital stay

Duration of hospital stay was reported in five studies. One of these was excluded from the meta-analysis as all procedures were performed as a day case. No differences in length of stay were found between the two study groups (MD −0·01, 95 per cent c.i. −0·18 to 0·16; $P = 0{\cdot}94$; $I^2 = 27$ per cent) (*Fig. S6*, supporting information).

Return to normal activity

Time to return to normal activity was reported in two studies. Meta-analysis revealed a statistically significant difference favouring the NS group (MD 0·30, 95 per cent c.i. 0·03 to 0·57; $P = 0{\cdot}03$; $I^2 = 0$ per cent) (*Fig. S7*, supporting information).

Discussion

Minimally invasive inguinal hernia repair has gained broad acceptance[22], with TEP and laparoscopic TAPP repairs being the most popular approaches today. Dissection of the preperitoneal space without damage to the peritoneum, and identification of key anatomical structures such as vas deferens, epigastric and femoral vessels, is of utmost importance for a safe and successful TEP hernia repair. In patients with a history of lower abdominal surgery, entering the preperitoneal space and performing a safe dissection can be challenging, a view based mostly on personal surgical experience as existing data on this subject are limited.

The present study examined the risk of intraoperative complications, the most frequent one being major bleeding (25 patients), which was significantly more common in the PS group. Regarding visceral injury, a single case of bladder perforation was reported in a patient who had undergone surgery previously and had excessive adhesions[10]. Peritoneal tear was not always considered an intraoperative complication. It is clinically relevant only if it affects the extraperitoneal working space volume. The rate of all intraoperative peritoneal lacerations was significantly lower in patients without previous surgery. Peritoneal tears and technical difficulties were the two most frequent reasons for conversion, which was more common in the PS group. In some instances, the peritoneal defect can be sealed either with clips or by intracorporeal suturing, but large defects require conversion to open hernia repair or TAPP repair. TAPP repair has been studied in a small series[14] of 20 patients with previous abdominal surgery, namely radical prostatectomy, and the authors concluded that it is a safe and effective approach.

The overall postoperative morbidity rate was significantly lower in the NS group, but only with the multiport TEP method ($P = 0{\cdot}004$). Experience with single-port TEP in patients with previous abdominal surgery remains limited[12,13,23].

Regarding chronic groin pain, no significant difference was noted between the two study groups. These results, however, are relatively short term, with follow-up ranging from 1·5 to 25 months after surgery.

There are some limitations to discuss. A degree of heterogeneity exists with regard to the type of previous surgery included in the study group. Three studies considered any surgery, and two included prostatectomy and appendicectomy, whereas another considered previous prostatectomy an exclusion criterion. Recurrent hernias were excluded from one study. In addition, the level of surgical expertise among operating surgeons was stated in only two studies. Three other studies reported that the operating surgeon was either a consultant or staff surgeon, and no information on surgical experience was provided in two. Finally, it should be acknowledged that the major limitation of the study is the inherent methodological disadvantage of meta-analysis of cohort studies, resulting in selection bias.

The results suggest that most outcomes were inferior after TEP repair in patients with previous abdominal surgery. TEP hernia repair is technically challenging, and in patients with a history of abdominal surgery should be undertaken only by an experienced surgeon. Alternatively, open inguinal hernia repair may be considered.

Disclosure

The authors declare no conflict of interest.

References

1 Jähne J. [Surgery of inguinal hernia.] *Chirurg* 2001; **72**: 456–469.

2 Dulucq JL. [Treatment of inguinal hernia by insertion of a subperitoneal patch under pre-peritoneoscopy.] *Chirurgie* 1992; **118**: 83–85.
3 Simons MP, Aufenacker T, Bay-Nielsen M, Bouillot JL, Campanelli G, Conze J *et al.* European Hernia Society guidelines on the treatment of inguinal hernia in adult patients. *Hernia* 2009; **13**: 343–403.
4 Zuiki T, Ohki J, Ochi M, Lefor AK. Laparoscopic totally extraperitoneal (TEP) inguinal hernia repair in patients with previous lower abdominal surgery. *Surg Endosc* 2018; [Epub ahead of print].
5 Ramshaw BJ, Tucker J, Duncan T, Heithold D, Garcha I, Mason EM *et al.* The effect of previous lower abdominal surgery on performing the total extraperitoneal approach to laparoscopic herniorrhaphy. *Am Surg* 1996; **62**: 292–294.
6 Paterson HM, Casey JJ, Nixon SJ. Totally extraperitoneal laparoscopic hernia repair in patients with previous lower abdominal surgery. *Hernia* 2005; **9**: 228–230.
7 Dulucq JL, Wintringer P, Mahajna A. Totally extraperitoneal (TEP) hernia repair after radical prostatectomy or previous lower abdominal surgery: is it safe? A prospective study. *Surg Endosc* 2006; **20**: 473–476.
8 Al-Sahaf O, Al-Azawi D, Fauzi MZ, Cunningham FO, McGrath JP. Totally extraperitoneal laparoscopic inguinal hernia repair is a safe option in patients with previous lower abdominal surgery. *J Laparoendosc Adv Surg Tech A* 2008; **18**: 353–356.
9 Chung SD, Huang CY, Chueh SC, Tsai YC, Yu HJ. Feasibility and safety of total extraperitoneal inguinal hernia repair after previous lower abdominal surgery: a case–control study. *Surg Endosc* 2011; **25**: 3353–3356.
10 Elshof JW, Keus F, Burgmans JP, Clevers GJ, Davids PH, van Dalen T. Feasibility of right-sided total extraperitoneal procedure for inguinal hernia repair after appendectomy: a prospective cohort study. *Surg Endosc* 2009; **23**: 1754–1758.
11 Le Page P, Smialkowski A, Morton J, Fenton-Lee D. Totally extraperitoneal inguinal hernia repair in patients previously having prostatectomy is feasible, safe, and effective. *Surg Endosc* 2013; **27**: 4485–4490.
12 Lin CD, Wu CH, Liu YB, Tsai YC. Feasibility and safety of laparoendoscopic single-site surgery of total extraperitoneal inguinal hernia repair after previous open groin hernia repair: a comparative study. *Surg Endosc* 2016; **30**: 2086–2089.
13 Wakasugi M, Suzuki Y, Tei M, Anno K, Mikami T, Tsukada R *et al.* The feasibility and safety of single-incision totally extraperitoneal inguinal hernia repair after previous lower abdominal surgery: 350 procedures at a single center. *Surg Today* 2017; **47**: 307–312.
14 Claus CM, Coelho JC, Campos AC, Cury Filho AM, Loureiro MP, Dimbarre D *et al.* Laparoscopic inguinal hernioplasty after radical prostatectomy: is it safe? Prospective clinical trial. *Hernia* 2014; **18**: 255–259.
15 Lau H, Patil NG. Impact of previous appendectomy on the outcomes of endoscopic totally extraperitoneal inguinal hernioplasty. *Surg Laparosc Endosc Percutan Tech* 2004; **14**: 257–259.
16 Park JH, Choi YY, Kyung YH. The feasibility of laparoscopic total extraperitoneal (TEP) herniorrhaphy after previous lower abdominal surgery. *J Korean Surg Soc* 2010; **78**: 405–409.
17 Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med* 2009; **6**: e1000097.
18 Wells G, O'Connell D, Peterson J, Welch V, Losos M, Tugwell P. *The Newcastle–Ottawa Scale (NOS) for Assessing the Quality of Nonrandomized Studies in Meta-analyses.* http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp [accessed 10 February 2019].
19 Shea BJ, Reeves BC, Wells G, Thuku M, Hamel C, Moran J *et al.* AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. *BMJ* 2017; **358**: j4008.
20 Hozo SP, Djulbegovic B, Hozo I. Estimating the mean and variance from the median, range, and the size of a sample. *BMC Med Res Methodol* 2005; **5**: 13.
21 Higgins JPT, Deeks JJ (eds). *Cochrane Handbook for Systematic Reviews of Interventions. Version 5.1.0* [updated March 2011]. The Cochrane Collaboration. www.cochrane-handbook.org [accessed 1 March 2011].
22 Neumayer L, Giobbie-Hurder A, Jonasson O, Fitzgibbons R Jr, Dunlop D, Gibbs J *et al.*; Veterans Affairs Cooperative Studies Program 456 Investigators. Open mesh *versus* laparoscopic mesh repair of inguinal hernia. *N Engl J Med* 2004; **350**: 1819–1827.
23 Cardinali L, Mazzetti CH, Cadenas Febres A, Repullo D, Bruyns J, Dapri G. Prospective randomized study comparing single-incision laparoscopic *versus* multi-trocar laparoscopic totally extraperitoneal (TEP) inguinal hernia repair at 2 years. *Surg Endosc* 2018; **32**: 3262–3272.

Supporting information

Additional supporting information can be found online in the Supporting Information section at the end of the article.

*Fig 1-3 modifiziert nach [52].

2.5 Electric cauterization of the hernia sac in laparoscopic ventral hernia repair reduces the incidence of post-operative seroma: a propensity score-matched analysis. [Appendix E] [53]

Despite an overall improved outcome, post-operative formation of seroma remains a common complication after laparoscopic ventral and incisional hernia repair. This paper examined the novel hypothesis that cauterization of the hernia sac without concomitant closure of the fascia defect significantly reduces the rate of postoperative seromas. In this study twenty cases of conventional IPOM repair (sIPOM) were matched 1:1 to twenty cases of IPOM with cauterization of the hernia sac (csIPOM). No postoperative seroma was noted in any of the cases in the csIPOM group in contrast to five patients (25%) in the control group [csIPOM vs sIPOM: 0 vs 25% (n=5), $p<0.05$].

Operative time was found to be higher in the csIPOM group, nevertheless without reaching statistical significance [csIPOM vs sIPOM (time in min ± SD): 64.4±37.7 vs 46.7±13.9, $p=0.057$]. Days on post-operative analgesic medication [csIPOM vs sIPOM (days ± SD): 4.05±1.93 vs 4.5±1.7, $p=0.4$], as well as length of in-hospital stay [csIPOM vs sIPOM (days ± SD): 5.25±1.9 vs 5.2±2.1, $p=0.9$] were also found to be similar.

In conclusion, the above study confirmed the hypothesis that hernia sac cauterization in laparoscopic IPOM repair can significantly reduce the rate of postoperative seromas.

Hernia (2018) 22:747–750
https://doi.org/10.1007/s10029-018-1790-4

ORIGINAL ARTICLE

Electric cauterization of the hernia sac in laparoscopic ventral hernia repair reduces the incidence of postoperative seroma: a propensity score-matched analysis

Dimitrios Prassas[1] · F.-J. Schumacher[1]

Received: 4 November 2017 / Accepted: 9 June 2018 / Published online: 14 June 2018

Abstract

Background Laparoscopic intraperitoneal mesh repair has become one of the most commonly performed minimally invasive procedures. Nevertheless, despite improved overall outcome, postoperative seroma formation remains the most frequent complication. Our objective was to investigate the effectiveness of cauterization of the hernia sac in terms of reducing the incidence of postoperative seroma formation.

Methods A retrospective analysis of 94 patients who underwent standard laparoscopic intraperitoneal mesh repair without closure of the central defect (sIPOM) between June 2011 and December 2014 was conducted. In 20 of those cases, electric cauterization of the hernia sac was additionally performed (csIPOM). One-to-one propensity score analysis was conducted to overcome patient selection bias between the two surgical techniques. The case–control group was matched by gender, body mass index (BMI), patient comorbidities, and surface of the hernia defect. Patient demographics, pre- and postoperative pain score (using a ten-point Likert scale), operative data, and complications were collected. At follow-up, postoperative seroma, hernia recurrence, and chronic pain were evaluated.

Results Patient demographics, hernia size, comorbidities, and BMI were similar between the two groups. The csIPOM patient group had significantly lower rate of seroma formation, compared to the sIPOM control [csIPOM vs. sIPOM 0 vs. 25% ($n=5$), $p<0.05$]. There was no difference noted regarding postoperative pain between the two techniques. Hernia recurrence rate was found to be higher in the sIPOM group [csIPOM vs. sIPOM 0 vs 12.5% ($n=2$), $p<0.05$].

Conclusion The present study confirms our hypothesis that laparoscopic sIPOM combined with electric cauterization of the hernia sac (csIPOM) significantly reduces the rate of postoperative seroma compared to the sIPOM technique in patients with ventral and incisional hernias. Further randomized trials are required to verify our findings.

Keywords Laparoscopic ventral hernia repair · Laparoscopic intraperitoneal onlay mesh · Postoperative seroma · Hernia sac cauterization

Introduction

Since its first introduction 15 years ago [1], standard laparoscopic intraperitoneal onlay mesh repair (sIPOM) has gained popularity and acceptance among surgeons as it significantly reduces postoperative morbidity, recurrence rate, and hospital stay length compared to the open approach [2].

Despite that, postoperative seroma formation remains a common occurence that can evolve in different ways ranging from minor complications such as patient dissatisfaction due to poor esthetic outcome, to serious septic complications. The additional intra- or extracorporal closure of the hernia defect (IPOM-Plus) was introduced, among other reasons, to reduce the incidence of postoperative seroma with its effectiveness regarding that matter remaining equivocal [3]. As an attempt to address that issue, we used a novel technique of sIPOM repair combined with electric cauterisation of the hernia sac (csIPOM) and assessed its efficacy and safety compared to the sIPOM technique by conducting a retrospective cohort analysis with a propensity matched control.

✉ Dimitrios Prassas
dimitrisprassas@yahoo.gr

[1] Department of Surgery, Katholisches Klinikum Oberhausen, Teaching Hospital of the University of Duisburg-Essen, Nürnberger Str. 10, 46117 Oberhausen, Germany

Patients and methods

Objectives and study design

Between June 2011 and December 2014, a total of 117 patients underwent elective laparoscopic IPOM repair in our institution. Twenty-three cases of IPOM-Plus were excluded from the study, leaving 74 cases of sIPOM and 20 cases of csIPOM. After propensity match score analysis, 20 cases of the sIPOM group were compared with 20 cases of the csIPOM group. This analysis was performed to overcome patient selection bias between the two surgical techniques. Patient data were collected electronically from our computer-based patient records database. Patients were asked to assess the severity of symptoms using a ten-point Likert scale preoperatively, 48 h postoperatively and on follow-up that was conducted by means of an outpatient appointment where two surgeons (DP and FJS) evaluated the patients for postoperative seroma, hernia recurrence chronic pain, and/or other potential complications.

As seroma was defined the clinically apparent and/or radiologically/ultrasonographically evident collection of fluid at the area of the hernia sac.

Surgical technique

All cases were operated in our institution by five surgeons with expertise in advanced laparoscopic surgery. One surgeon (DS) favored the csIPOM repair technique. Standard IPOM repair using three trocars was performed by placing a polypropylene mesh (PROLENE™, Ethicon) with 5 cm overlapping the borders of the hernia defect. The hernia sac was not resected. A closure of the hernia defect was not performed. Four transfascial sutures were placed in each corner of the mesh using the suture passer to ensure its correct intraperitoneal positioning. Additional fixation with absorbable tacks in double-crown technique was performed. Patients in the csIPOM group were operated with the exact same technique, with the only modification being the cauterization with monopolar cautery of the hernia sac and its surrounding peritoneum after reduction of the hernia contents, when necessary.

The cauterization is conducted in three stages. First, the peritoneal surface is cauterized up to 1 cm peripherally of the edges of the hernia defect using the broad surface of the laparoscopic scissor blades. Then, the same instrument is used to cauterize the anterior surface of the hernia sac after the latter has been retracted intraabdominally with a grasper. Finally, the posterior surface of the hernia sac is cauterized with the scissors in the same fashion (Fig. 1).

Statistical analysis

Descriptive statistics were calculated for the patients' data and were presented as mean ± SD. Continuous variables were compared using the paired Student's t test. Categorical variables between the two groups were compared using the Binomial exact test, since McNemar's test was not applicable due to our relatively small number of observations. One-to-one propensity score matching was performed to overcome bias arising from the lack of randomization. Patients were matched according to age, gender, BMI, ASA class, and hernia defect area. Statistical significance was set at a level of $p \leq 0.05$. Statistical analysis was performed using SPSS for Windows and Mac (v22.0, SPSS Inc, Chicago, IL).

Ethics

The study was approved by the ethics committee of our institution. An informed consent was obtained from all patients. The study was registered in Research Registry (UIN 2716).

Fig. 1 Cauterization: cauterization is conducted in three stages. First, the peritoneal surface is cauterized up to 1 cm peripherally of the edges of the hernia defect using the broad surface of the laparoscopic scissor blades. Then, the same instrument is used to cauterize the anterior surface of the hernia sac after the latter has been retracted intraabdominally with a grasper. Finally, the posterior surface of the hernia sac is cauterized with the scissors in the same fashion

Results

Patient characteristics

The study included 40 cases of primary reducible incisional or ventral hernias, which underwent elective laparoscopic IPOM repair, between June 2011 and August 2014. They were classified into two groups: the sIPOM group and the csIPOM group, consisting of 20 cases each. There were no significant differences in age, gender, BMI, ASA class, or hernia defect area on propensity score matching. The baseline characteristics of the study population are presented in Table 1.

Intraoperative data

All procedures were carried out laparoscopically with no case of conversion to open surgery. One intraoperative bleeding complication in the sIPOM group was related to lesion of an epigastric vessel and was treated with transfascial haemostatic stitch. No intraoperative complications occurred in the csIPOM group. Operative time was shorter for the sIPOM group (operative time in minutes csIPOM vs. sIPOM 64.4, SD 37.7 vs. 46.7, SD 13.9, $p=0.057$). The sIPOM group consisted of 14 umbilical hernias, 4 incisional hernias, and 2 epigastric hernias, whereas the csIPOM group consisted of 13 umbilical hernias, 6 incisional hernias, and 1 epigastric hernia (Table 2).

Postoperative outcomes and seroma occurrence

Postoperative length of stay was similar for both groups (csIPOM vs. sIPOM 5.25, SD 1.9 vs. 5.2, SD 2.1, $p=0.9$). All patients appeared to have mild pain 48 h postoperatively, without any statistically significant difference noted between the two groups (csIPOM vs. sIPOM 2.4, SD 1.46 vs. 2.35, SD 0.87, $p=0.8$). The number of days patients required postoperative analgetic medication was similar for both groups (csIPOM vs. sIPOM 4.05, SD 1.93 vs. 4.5, SD 1.7, $p=0.44$).

Table 1 Demographic data of the two groups

	csIPOM ($n=20$)	sIPOM ($n=20$)
Age ± SD (years)	58.2 ± 13.7	58.7 ± 14.1
Gender (M:F)	11:9	14:6
BMI ± SD (kg/m^2)	31.1 ± 8	32.2 ± 6.5
ASA I	15% ($n=3$)	5% ($n=1$)
ASA II	55% ($n=11$)	65% ($n=13$)
ASA III	30% ($n=6$)	30% ($n=6$)
Preoperative pain ± SD (min: 0–max: 10)	1.85 ± 2.1	1.47 ± 1.4

Table 2 Operative data and early postoperative outcome

	csIPOM	sIPOM	p
Operative time ± SD (in minutes)	64.4 ± 37.7	46.7 ± 13.9	0.057
Hernia size ± SD (in cm^2)	12.45 ± 10.7	12.8 ± 12	0.9
Immediate postoperative pain ± SD (min: 0–max: 10)	2.4 ± 1.4	2.35 ± 0.9	0.8
Days on analgetic medication ± SD	4.05 ± 1.93	4.5 ± 1.7	0.4
Length of stay in days ± SD	5.25 ± 1.9	5.20 ± 2.1	0.9
Postoperative seroma (n)	0	25% ($n=5$)	<0.05

There was no mortality. The early postoperative morbidity was exclusively seroma-associated. There was a statistically significant difference noted in the development of postoperative seroma between the two patient groups [csIPOM vs. sIPOM 0 vs. 25% ($n=5$), $p<0.05$]. Four seromas occurred in the early postoperative period and resolved spontaneously, whereas one persistent seroma that lasted over 3 months was treated with repeated needle aspirations.

Follow-up

The follow-up rate was 75% (15/20) with a median follow-up of 18 months (9–26) for the csIPOM group and 80% (16/20) with a median follow-up of 18 months (7–28) for the sIPOM group. There was a significant difference observed in the recurrence rate between the two groups [csIPOM vs. sIPOM 0 vs 12.5% ($n=2$), $p<0.05$]. The differences regarding chronic pain at follow-up between the groups were insignificant (csIPOM vs. sIPOM 0.53, SD 1.35 vs. 0.69, SD 1.25, $p=0.74$) (Table 3).

Discussion

Seroma formation is the most commonly reported complication following mesh repair of abdominal wall hernia with an incidence ranging from 3 to over 50% [4]. The cause of this notable variability lies in the lack of a consistent definition in the literature. In the present study, seroma was defined as a bothersome, fluctuant, tense, and clinically and/

Table 3 Follow-up

	csIPOM	sIPOM	p
Follow-up % (n)	75% ($n=15$)	80% ($n=16$)	0.99
Follow-up ± SD (in months)	18 ± 5.4	19.1 ± 5.7	0.6
Pain at follow-up (min: 0–max: 10)	0.53 ± 1.35	0.69 ± 1.25	0.74
Hernia recurrence (n)	0	12.5% ($n=2$)	<0.05

or sonographically evident collection of fluid between the implanted mesh and the abdominal wall. The postoperative accumulation of serous fluid is, to a certain extent, an expected physiologic reaction that should not be regarded as a complication per se if it is not clinically evident and/or symptomatic. Nevertheless, it is well known that seromas can persist and potentially progress to deep surgical site infections especially after multiple aspirations [5]. Postoperative seroma formation is believed to be a direct consequence of the foreign body reaction triggered by the prosthetic mesh. This results in the accumulation of aseptic inflammatory exudate, mainly consisting of monocytes and macrophages [6]. The reduction of the hernia contents leaves an empty hernia sac that is dorsally sealed with the mesh, forming a dead space and further amplifying the effect of the aforementioned mechanism. The transcutaneous closure of the fascia defect prior to onlay mesh reinforcement (IPOM-Plus) has been introduced to eliminate the dead space and prevent seroma formation and hernia recurrence. The most recent systematic review regarding that matter finds that the majority of papers are contradictory, with the authors stating that the effectiveness of the technique regarding prevention of seroma formation remains equivocal [3].

We hypothesized that electric cauterization of the hernia sac and the surrounding peritoneum reduces the rate of postoperative seroma.

We believe that the main mechanism is the elimination of the dead space by the formation of adhesions between the mesh and the cauterized tissue.

Moreover, parietal peritoneum and, more specifically, the mesothelial cells that are known to play an essential role in the mesh–tissue interface producing cytokines and chemokines and subsequently inflammatory exudate, are destroyed [7]. The first report of this technique combined with routine suturing was described 16 years ago demonstrating favorable results regarding postoperative seroma rate [8]. Our report is, to our knowledge, the first to investigate the effects of cauterization alone, without closure of the central defect. A statistically significant difference in the development of postoperative seroma between the two patient groups could be demonstrated.

An obvious limitation of our study is its retrospective nature, lack of randomization, and relatively low number of cases. However, the results support our hypothesis and highlight the need for multi-center randomized trials to reach solid conclusions in this area.

Conclusions

The present study confirms our hypothesis that laparoscopic sIPOM combined with electric cauterization of the hernia sac (csIPOM) significantly reduces the rate of postoperative seroma compared to the sIPOM technique in patients with ventral and incisional hernias. Larger-scale trials will be needed to verify our findings.

Author contributions Dr. DP designed the study collected the data, analyzed the data, and wrote the manuscript. Dr. F-JS designed the study and wrote the manuscript.

Compliance with ethical standards

Conflict of interest Drs. Dimitrios Prassas and Franz-Josef Schumacher declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Human and animal rights This article does not contain any studies with animals performed by any of the authors.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. LeBlanc KA, Booth WV (1993) Laparoscopic repair of incisional abdominal hernias using expanded polytetrafluoroethylene: preliminary findings. Surg Laparosc Endosc 3(1):39–41
2. Sauerland S, Walgenbach M, Habermalz B, Seiler CM, Miserez M (2011) Laparoscopic versus open techniques for ventral or incisional hernia repair. Cochrane Database Syst Rev 16(3):CD007781
3. Suwa K, Okamoto T, Yanaga K (2016) Closure versus non-closure of fascial defects in laparoscopic ventral and incisional hernia repairs: a review of the literature. Surg Today 46(7):764–773
4. Mercoli H, Tzedakis S, D'Urso A, Nedelcu M, Memeo R, Meyer N, Vix M, Peretta S, Mutter D (2017) Postoperative complications as an independent risk factor for recurrence after laparoscopic ventral hernia repair: a prospective study of 417 patients with long-term follow-up. Surg Endosc 31(3):1469–1477
5. Toy FK, Bailey RW, Carey S, Chappuis CW, Gagner M, Josephs LG, Mangiante EC, Park AE, Pomp A, Smoot RT Jr, Uddo JF Jr, Voeller GR (1998) Prospective multicenter study of laparoscopic ventral hernioplasty: preliminary results. Surg Endosc 12(7):955–959
6. Bernatchez SF, Parks PJ, Gibbons DF (1996) Interaction of macrophages with fibrous materials in vitro. Biomaterials 17(21):2077–2086
7. Flessner MF (2005) The transport barrier in intraperitoneal therapy. Am J Physiol Renal Physiol 288(3):F433–F442
8. Tsimoyiannis EC, Tsimogiannis KE, Pappas-Gogos G, Nikas K, Karfis E, Sioziou H (2008) Seroma and recurrence in laparoscopic ventral hernioplasty. JSLS 12(1):51–57

*Fig. 1 modifiziert nach [53]

3. DISCUSSION

Paper A [49]

Paper A was published at a time when data on the laparoscopic repair of large paraesophageal hiatal hernias was limited. It is of particular interest as it focuses on suture repair of the hiatal defect without any mesh reinforcement. This choice of repair was based on data demonstrating serious complications after routine use of prosthetic materials at the area of the gastroesophageal junction [54]. A case-series of 28 interventions with mesh reinforcement of the hiatal closure identified new-onset post-operative dysphagia as the most common presenting symptom followed by epigastric pain and heartburn. Moreover, 23 out of 28 cases required re-operation with the most common adverse event observed being esophageal mesh erosion. Data from paper A demonstrate significantly lower intensity of epigastric pain (p=0,028) and no significant increase of dysphagia after primary hiatal closure alone (p=0,8), supporting the findings of the above-mentioned case series. At this point, it must be noted that complications seem to be independent of the type of mesh material or the configuration used, with the exception of biologic meshes that were not found to be responsible for esophageal erosion [54]. In regard to recurrence rates, the use of prosthetic mesh to reinforce the primary suture repair has been shown to demonstrate lower recurrence rates on short-term follow-up. This effect was, nevertheless, not present at long-term follow up. At four years similar recurrence rates were noted between the mesh and no-mesh study groups (54% vs. 59%; p=0,7) [55]. Meta-analytic data of four randomized controlled trials pooling the outcome of 406 cases show that mesh reinforcement of the crural closure reduced recurrence rates 16% vs. 27%) nevertheless not at a statistically significant level.

Generally, despite the appeal of mesh reinforcement, consensus is lacking. Considering the fact that none of the reports used a mesh reinforcement without previously closing the crurae, it may be safely said that a proper suture hiatoplasty is not intended to be replaced by mesh placement alone.

A second characteristic of the studied cohort in paper A is the fact that the majority of the repairs performed were combined with an anti-reflux procedure (94%, n=52). Gastroesophageal reflux symptoms are common among patients with large

paraesophageal hernias. Migration of the gastroesophageal junction into the mediastinum, the anatomically altered hiatus oesophagei, and the distorted, or in some cases even non-existent, angle of His, contribute to the impairment of the lower esophageal sphincter's functionality. As a result, most of the reports about paraesophageal hernia repair have included a fundoplication as part of the repair. A recent randomized controlled trial of 40 patients found significantly decreased reflux in the hernia repair with the fundoplication group compared to the hernia repair alone without concomitant fundoplication control group at 12-month follow-up. The most fearsome complication after anti-reflux procedures, dysphagia, did not differ significantly between the two groups [56]. Follow-up data from paper A support the above-mentioned findings. All patients who participated in the follow-up were dually operated with hiatoplasty and Nissen fundoplication. Symptom scores were post-operatively significantly lower for heartburn ($p<0,001$) while dysphagia and bloating were not found to differ pre- and postoperatively.

Paper B [50]

Ever since the use of polypropylene mesh was introduced by Usher in the late 1990s for inguinal hernia repair, there has been ongoing debate regarding the most appropriate prosthetic material in different surgical settings [57]. Today, with more than 130 meshes being commercially available, the choice for the most appropriate one has become a rather challenging issue. The most commonly used materials in the modern era remain polypropylene and polyester polymers. An ever-growing variety of hybrid and composite meshes are being developed that combine desired characteristics in order to boost foreign material integration and improve adhesion formation. The basic goal of modern mesh manufacturers has been to produce a prosthetic material that possesses the minimum of bio-mechanical properties needed to withstand the in vivo tensions of the abdominal wall while, at the same time, triggering a limited foreign body reaction. Overall structural stability of the mesh depends vastly on the density of the material, most commonly termed as 'weight'. Even though strict margins between various weight categories do not exist, the most commonly published density ranges include: heavyweight (>90 g/m^2), medium weight (50-90 g/m^2), lightweight (35-50 g/m^2) and ultralightweight (<35 g/m^2) [58]. The

maximum intra-abdominal pressure generated in a healthy adult is estimated at approximately 170 mmHg [59]. Using Laplace's Law, the maximum tensile strength is calculated at 16 N/cm. Taking the above into consideration, heavy-weight meshes display four to six times the maximum tensile strength of the abdominal wall at the cost of significant inflammatory response, fibrosis and mesh shrinkage leading to foreign object feeling and, possibly, chronic pain symptoms [60] . This led the biomedical industry to produce meshes with larger pores between the mesh fibers. Pore size is proportionate to tissue ingrowth and incorporation to the groin tissues. Moreover, larger-pore meshes allow an easier macrophage passage in case of infection and enhanced fluid transport across the mesh, reducing seroma rates [60].
An additional titanium coating to the polypropylene meshes has been shown to reduce chronic inguinal pain and foreign body sensation [61]. Although hundreds of publications exist comparing different mesh types, evidence regarding a head-to-head comparison of standard medium-weight polypropylene mesh and a low-weight tetanized mesh in TEP inguinal hernia repair is scarce. In paper B, we presented the first single-center data comparing the two above mentioned mesh categories with regard to short- and long-term outcome. In order to eliminate factors other than the type of mesh itself, only cases of unilateral hernias without the use of any fixation device were included. There were no differences noted between the two study groups regarding direct postoperative and chronic pain. Recurrence rate was also found to differ insignificantly between the two groups. In conclusion, no short- or long-term advantages could be demonstrated for any of the two investigated meshes over the other. This fact has not gone unnoticed among the hospital supply chain and the mesh industry, both of which attempt to limit vendor and mesh choice for economic benefits. This practice could force surgeons into a very small spectrum of prosthetic mesh choices in their surgical armamentarium which may not be optimal for all patients [62]. Hence, more single-center studies are needed conducting head-to-head comparison of various mesh types in order to draw more concrete conclusions about this crucial aspect of hernia repair.

Papers C [51] and D [52]

The motivation to analyze our single-center data and publish paper C derived from the fact that the outcome of laparoscopic TEP inguinal hernia repair has only scarcely been investigated in patients with previous lower abdominal surgery. Even today, only eight comparative cohort studies exist, including paper C. The majority of surgeons regard prior abdominal surgery as an absolute contraindication for the extra-peritoneal approach. Associated adhesions of the myopectineal orifice render complete dissection of the latter and adequate identification of key anatomic landmarks, without any violation of the preperitoneal envelopes' integrity a rather challenging surgical task. Nevertheless, numerous institutions specializing in minimally invasive surgery where the only absolute contraindication to laparoscopic TEP repair is inability to tolerate anesthesia, do exist.

Personal experience has shown that the use of a spherical balloon dissector alone can sufficiently expand the pre-peritoneal space and provide an adequate field where the two working trocars can be inserted. Usually all three trocars are inserted over the mid-line. When appropriate, they can be inserted laterally in order to avoid any significant adhesions after previous median laparotomy. Care must be taken not to cause any peritoneal tears by excessively inflating the balloon. Once all trocars are in place, adhesiolysis continued with gentle and meticulous dissection. It is of paramount importance that the myopectineal orifice is adequately developed [63]. At least 2 cm between the bladder and the ligament of Cooper should be dissected in order to facilitate a more anatomical positioning of the mesh into the space of Retzius and ensure that mesh displacement after bladder distention does not occur. The peritoneum should be dissected laterally to allow for adequate placement of the mesh. Care should be taken to leave a fat layer on the lateral abdominal wall in order to avoid bleeding and minimize the risk of damaging laterally lying nerve branches.

At this point it must be stated that the distorted anatomy of the previously operated lower abdominal wall complicates all of the above-mentioned surgical steps, proportionate to the degree of adhesions of the myopectineal space.

The hypothesis of paper C was that laparoscopic TEP repair is a feasible and safe approach in the hands of experienced surgeons, regardless of the patients' surgical history. Intra- and post-operative morbidity were found to be comparable in both

patient groups. Even at follow-up, no differences were noted with respect to chronic inguinal pain and recurrence rate.

Since data was derived from an institution with expertise in laparoscopic TEP repair, the question of the extent to which the findings of paper C can be generalized beyond the study itself, remains open. In order to shed light in this direction, the first ever meta-analysis comparing patients with and without previous surgery was conducted. In paper D overall seven studies were included involving a total of 1657 cases. Primary outcomes were intra- and post-operative morbidity. For both outcomes, a statistically significant difference was noted favoring the patient group without prior surgery. Additionally, the same patient group was favored with regard to the majority of secondary endpoints, such as major intraoperative bleeding and conversion rate.

The conclusions drawn from the meta-analytic data of paper D are not in line with those reached from paper C, a single center cohort. The hypothesis for this discrepancy is that, contrary to paper C, paper D provided data generated by institutions of unclear surgical expertise on the field. The level of experience was clearly stated in only two out of seven included studies of the meta-analysis. Three further studies reported that the operating surgeon was either a consultant or staff surgeon and in two other studies there was no information provided at all. Interestingly, in both papers in which the operating surgeon(s) had a high level of expertise , the outcome is in line with the findings of paper C [64] [65].

The high degree of heterogeneity between the existing papers, with regard to the types of previous surgery, is a further factor that could explain the discrepancy of results. In paper C, it was chosen to exclude patients with previous laparoscopic appendectomy and previous open anterior hernia repair as those approaches do not alter the anatomy of the myopectineal orifice and have virtually no effect on the surgical field of a TEP repair. On the contrary, four out of seven meta-analyzed studies in paper D report that any type of lower abdominal surgery was included. This fact probably reduces the quality of the conducted studies by generating inhomogeneous patient groups which are not appropriate for the control of the null hypothesis.

In conclusion, after the conduction of two different studies, it can be stated that laparoscopic TEP inguinal hernia repair in patients with previous lower abdominal

surgery is technically challenging and should be undertaken exclusively by surgeons with experience in the field of advanced laparoscopic surgery.

Paper E [53]

Postoperative seroma formation after laparoscopic intraperitoneal onlay mesh repair (IPOM) is one of the most common occurrences after this procedure with various effects on patients, ranging from minor to major septic complications. Seroma is generally defined as the collection of serum, lymphatic fluid and liquefied fat in a contained space. Seromas develop in virtually all patients during the early post-operative course after hernia surgery, without being necessarily symptomatic. Therefore, a consistent definition of seroma in the literature is lacking, a fact that results in a wide range of reported incidence ranging from 0,5 to 78% after standard laparoscopic IPOM repair (sIPOM) [66] [67].

Transcutaneous closure of the fascia defect is a method that eliminates dead space, nevertheless its effectiveness regarding prevention of seroma formation has not yet been proven [68]. The effect of closure of the hernia defect in laparoscopic IPOM repair (IPOM-Plus) on seroma formation has been investigated, demonstrating mixed results. More specifically, the above-mentioned technique was compared to the sIPOM approach in the reports by Zeichen et al. [69] and by Clapp et al. [70] demonstrating post-operative seroma rates of 11,4% vs, 4.3% and 5,6% vs. 27,8% respectively. Moreover IPOM-Plus was not found to be superior to sIPOM in an RCT comparing the two methods, with regard to seroma formation [71].

Hernia sac cauterization was conceived as an alternative to IPOM-Plus. It was hypothesized that cauterization with monopolar current of the hernia sac and its surrounding peritoneum, without fascia defect closure, acts as a protective measure against seroma formation. We believe that this effect is based on two different mechanisms. The first mechanism is the destruction of the inflammatory exudate-producing mesothelial cells of the peritoneum. The second mechanism is the elimination of dead space by formation of adhesions between the prosthetic mesh and the cauterized tissue.

Paper E included 40 cases of primary reducible ventral hernias. One-to-one propensity score matching was performed in order to form two groups with weighted relevant risk-factors such as BMI and hernia defect area.

The patient group in which cauterization was performed was found to have significantly less seromas compared to the control group [0 vs. 25% (n=5), $p<0,05$].

The first report of this method, combined with IPOM-Plus was described 16 years ago, demonstrating favorable results regarding post-operative seroma rate [72]. To our knowledge, paper E is the first study to demonstrate the efficacy and safety of the above-mentioned technique without additional closure of the hernia defect. As our experience with cauterization in the setting of laparoscopic IPOM repair grows and our patient cohort increases, more data become gradually available in order to further verify the findings of our primary analysis.

4. SUMMARY

Even though laparoscopic hernia repair has proven itself over time as safe and feasible, its evolution continues as we approach the third decade of the twenty-first century. A continuous inflow of new technical approaches, new devices and new prosthetics exists, each conceived to further optimize our patients' outcome. The aim of this cumulative work is to shed light on current controversial issues of laparoscopic hernia surgery that largely remain unstudied.

The efficacy and safety of the laparoscopic approach was investigated in a series of patients with large type III and IV hiatal hernias, providing data supporting posterior hiatoplasty without routine mesh reinforcement of the hiatus. Moreover, concomitant Nissen fundoplication was found to significantly reduce heartburn without causing any new-onset dysphagia and/or bloating.

My next included work focused on the outcomes of laparoscopic total extraperitoneal hernia repair (TEP) using a standard weight polypropylene monofilament mesh with medium-sized pores or a lightweight titanium-coated mesh with large pores. No significant differences were noted in the clinical outcome between the two prosthetic materials.

I further investigated current controversies in the TEP hernia repair by examining the feasibility and safety of the technique in patients with a history of lower abdominal surgery. It was found that, in a specialized setting, previous lower abdominal surgery should not be considered a contraindication for laparoscopic TEP repair. In order to reveal the extent to which the findings of this single-center study can be generalized beyond the study itself, I conducted the first Meta-analysis of studies regarding this subject. The results showed that most outcomes were inferior in patients with previous abdominal surgery, suggesting that TEP repair in this patient group should be undertaken exclusively by surgeons with experience in the field of advanced laparoscopy.

My next work concentrated on the development of seroma after laparoscopic intraperitoneal onlay mesh repair of ventral/incisional hernias (IPOM). A novel technique of cauterization of the hernia sac without closure of the fascia defect was

investigated and was found to significantly reduce the rate of postoperative seromas, compared to the standard laparoscopic IPOM approach.
In conclusion, my habilitation thesis provides novel insights into multiple aspects of the ever-evolving field of laparoscopic hernia repair and constitutes a basis for research and further discussion on this subject that affects several thousands of patients worldwide.

Zusammenfassung

Obwohl sich die laparoskopische Hernienchirurgie seit Jahren als sicher durchführbar und praktikabel erwiesen hat, schreitet die Entwicklung dieser Methode auch in der dritten Dekade des 20. Jahrhunderts weiter voran. Stetig werden neue Zugangswege, Instrumente und Netze vorgestellt, mit dem Ziel das Outcome der Patienten weiter zu verbessern. Das Ziel dieser kumulativen Abhandlung ist es, ein Licht auf die stetigen Kontroversen der laparoskopischen Hernienversorgung zu werfen, von denen viele bis heute ohne wissenschaftliche Basis geführt werden. Die Effizienz und Sicherheit der laparoskopischen Versorgung großer Typ III und Typ IV Hiatushernien wurde an einer Serie von Patienten untersucht. Die erhobenen Daten sprechen für eine hintere Hiatoplastik ohne routinemäßige Netzimplantation. Des Weiteren führte eine simultane Fundoplikatio nach Nissen zu einer signifikanten Reduktion von retrosternalen Schmerzen ohne das Neuauftreten von Dysphagie oder *Gas-bloating* Phänomen zu begünstigen. Die nächste eingeschlossene Arbeit befasst sich mit der total extraperitonealen Hernioplastik (TEP) unter Verwendung von mittel-porigen, *standard-weight* Polypropylene Netzen versus großporigen, *light-weight* titanbeschichteten Netzen. Die Studie konnte keinen signifikanten Unterschied im Outcome bezüglich der verwendeten Materialien aufzeigen. Weiterhin habe ich die aktuelle Kontroverse bezüglich der Sicherheit und Anwendbarkeit der total extraperitonealen Leistenhernienversorgung (TEP) bei Patienten nach stattgehabten Eingriffen im Unterbauch beleuchtet. Die Studie zeigte, dass bei entsprechender Expertise eine vorangegangene Operation im Unterbauch keine absolute Kontraindikation zur TEP darstellt. In dem Bemühen herauszufinden in welchem Maße sich die Ergebnisse unserer Studie eignen, eine generelle Empfehlung auszusprechen,

habe ich eine Metaanalyse aller Studien zu diesem Thema durchgeführt. Die Ergebnisse dieser Metaanalyse zeigen ein schlechteres Outcome nach TEP im Falle vorangegangener Unterbaucheingriffe, so dass diese Methode nur Chirurgen mit ausgeprägter laparoskopischer Erfahrung empfohlen werden kann. Meine nächste eingeschlossene Arbeit befasst sich mit der Entstehung postoperativer Serome nach Intraperitonealer Onlay Mesh Plastik (IPOM) zur Versorgung ventraler Bauchwandhernien. Eine modifizierte Version der herkömmlichen IPOM Operation, bei welcher der Bruchsack elektrokoaguliert und die Bruchlücke nicht mittels zusätzlicher Fasziennaht verschlossen wurde, zeigte ein signifikant reduziertes Auftreten dieser Serome. Zusammenfassend bietet meine Habilitationsarbeit neue Einblicke in verschiedene Aspekte und Kontroversen der sich stetig weiterentwickelnden, laparoskopischen Hernienversorgung. Sie stellt eine Basis für weitere Forschung und Diskussion dar, in einem chirurgischen Feld das jährlich viele tausend Patienten weltweit betrifft.

5. ABBREVIATIONS

ASA	American Society of Anesthesiologists
BMI	Body Mass Index
IPOM	Intra-peritoneal onlay mesh repair
P	Pressure
r	Radius
RCT	Randomized controlled study
SD	Standard deviation
T	Tension
TAPP	Trans-abdominal pre-peritoneal repair
TEP	Totally extra-peritoneal repair
W	Wall thickness

6. ACKNOWLEDGEMENTS

An erster Stelle möchte ich mich bei Herrn Univ.-Prof. Dr. med. Wolfram Trudo Knoefel bedanken, der mich nicht nur stets in meiner klinischen und operativen Ausbildung unterstützt und geprägt hat, sondern darüber hinaus meine wissenschaftliche Tätigkeit gefördert hat. Besonders dankbar bin ich ihm für die kräftige Unterstützung meines Habilitationsverfahrens sowie die stetige Schaffung von Freiräumen um neben der klinischen Arbeit auch wissenschaftlich tätig sein zu können.

Ganz besonders möchte ich mich zudem bei Prof. Dr. med. Andreas Krieg bedanken. Seine exzellente wissenschaftliche Betreuung sowie die hervorragende Zusammenarbeit haben entscheidend dazu beigetragen, dass die Projekte, die dieser Habilitation zu Grunde liegen, erfolgreich durchgeführt werden konnten.

An dieser Stelle möchte ich auch Herrn Dr. med. Franz-Josef Schumacher danken, der mich durch seine fortwährende positive Motivation über all die Jahre darin bestärkt hat meine wissenschaftliche Arbeit zu intensivieren.

Allen anderen der nicht namentlich genannten Kolleginnen und Kollegen, die an den Forschungsprojekten beteiligt waren und damit auch zum Gelingen dieser Arbeit beigetragen haben, möchte ich selbstverständlich auch meinen Dank für die konstruktive Zusammenarbeit aussprechen.

Abschließend möchte ich meiner Familie danken, die mich zu jedem Zeitpunkt verlässlich und wohlwollend auf meinem Lebensweg begleitet hat. Insbesondere danke ich meiner Ehefrau Katerina für ihre bedingungslose Unterstützung, liebevolle Motivation und unendliche Geduld mit der sie mir in der gesamten Zeit zur Seite stand.

7. REFERENCES

[1] W. S. Haubrich. „Medical meanings: a glossary of word origins“, Philadelphia: American College of Physicians, 2003.

[2] J. F. Patino. „A history of the treatment of hernia“. In Nyhus LM, Condon RE, editors, 4th edition, Hernia, Philadelphia, Lippincott, 1995;3–15.

[3] W. Lau, „History of treatment of groin hernia,“ *World J Surg,* pp. 784-59, 26 2002.

[4] H. Delvin, A. Kingsworth, P. O'Dwyer „General introduction and history of hernia surgery. 2nd edition,“ in *Management of abdominal hernias*, London, Chapman & Hall.

[5] G. Saliceto, P. Pifteau und L. D. Rosenman, „The surgery of William of Saliceto : written in 1275,“ [Philadelphia, Pa.] : Xlibris Corp., ©2002.

[6] R. Margotta und L. Lewis, The nineteenth century, an illustrated history of medicine, Middlesex: Hamlyn, 1968.

[7] W. Bull, „Notes on cases of hernia which have relapsed after various operations for radical cure,“ Bd. 53, pp. 617-617, 1891.

[8] R. Read, „The development of inguinal herniorrhaphy,“ *Surg Clin North Am,* Bd. 64, pp. 185-196, 1984.

[9] E. Shouldice, „The Treatment of Hernia,“ *Ontario Med Rev,* Bd. 1, pp. 1-14, 1953.

[10] W. A, „Zur Radikaloperation des freien Leistenbruches,“ *Beitr chir (Festchr. Gewidmet Theodor Billroth),* Bd. 551, 1982.

[11] B. Anson, E. Morgan und C. Mc Vay, „Surgical anatomy of the inguinal region based upon a study of 500 body halves,“ *Surg gyn obst,* Bd. 111, pp. 707-25, 1960.

[12] H. Marcy, „The cure of hernia,“ *JAMA,* Bd. 8, pp. 589-592, 1887.

[13] R. Read und F. Usher, „Herniologist of the 20th century,“ *Hernia,* Bd. 3, pp. 167-71, 1999.

[14] P. Amid, A. Shulman und I. Lichtenstein, „Critical scrutiny of the open “tension-free” hernioplasty,“ *Am J Surg,* Bd. 165, pp. 369-71, 1993.

[15] L. Schlultz, J. Graber, J. Pietrafitta und D. Hickok, „Laparoscopic herniorraphy: a clinical trial preliminary results,“ *J Laparoendoscop Surg,* Bd. 1, Nr. 1, pp. 45-5, 1990.

[16] J. Duluq, „Treatment of inguinal hernia by insertion of a subperitoneal patch under pre-peritoneoscopy,“ *Chirurgie,* Bd. 118, Nr. 1-2, pp. 83-85, 1992.

[17] A. Park, J. Roth und S. Kavic, „Abdominal wall hernia. Current problems in surgery,“ *Curr Probl Surg,* Bd. 43, Nr. 5, pp. 326-375, 2006.

[18] J. Faylona, „Evolution of ventral hernia repair,“ *Asian Journal of endoscopic surg,* Bd. 10, Nr. 3, pp. 252-58, 2017.

[19] M. Bedewi, „Prevalence of adult paraumbilical hernia. Assessment by high resolution sonography: A hospital based study.,“ *Hernia,* Bd. 16, Nr. 1, p. 159, 2012.

[20] A. Kingsworth und L. B. K, „Hernias: Inguinal and incisional,“ *Lancet,* Bd. 362, pp. 1561-71, 2013.

[21] I. Rutkow und A. Robbins, „Demographi, classificatory and socioeconomic aspects of hernia repair in the United States," *Surg Clin North Am,* Bd. 73, Nr. 3, p. 413, 1993.

[22] S. Susmallian, O. Ponomarenko, R. Barnea und H. Paran, „Obturator hernia as a frequent finding during laparoscopic pelvic exploration: A retrospective observational study.," *Medicine (Baltimore),* Bd. 95, Nr. 27, p. e4102, 2016.

[23] T. Osman und A. Emam, „Risk factors for the development of flank hernias and bulges following surgical flank approaches to the kidney in adults," *Arab journal of urology,* Bd. 16, Nr. 4, pp. 453-459, 2018.

[24] A. Weston, „Hiatal hernia with Cameron lesions and erosions," *Gastrointest. Endosc. Clin. N. Am.,* Bd. 6, Nr. 4, pp. 671-679, 1996.

[25] F. De Meulder, M. Wojciechowski, G. Hubens und Ramet, „Female hydrocele of the canal of Nuck, a case report," *Eur J Pediatr,* Bd. 165, p. 193, 2006.

[26] D. 3. McClusky, P. Mirilas und O. Zoras, „Groin hernia: anatomical and surgical history," *Arch surg,* Bd. 141, p. 1035, 2006.

[27] A. Attah und J. Hudson, „The anatomy of the female gubernaculum is different from the male," *Aust N Z J,* Nr. 61, p. 380, 1991.

[28] D. Katz, „Evaluation and management of inguinal and umbilical hernias," *Pediatr. Ann,* Bd. 30, Nr. 12, pp. 729-35, 2001.

[29] L. 3. Scherer und J. Grosfeld, „Inguinal hernia and umbilical anomalies," *Pediatr Clin North Am,* Bd. 40, Nr. 6, pp. 1121-31, 1993.

[30] R. Kaiser und S. Singal, „Diaphragm," in *Surgical foundations.Essentials of thoracic surgery*, Philadelphia, elsevier mosby, 2004, p. 294.

[31] A. Winston, „Hiatal hernia with cameron ulcers and erosions," Bd. 6, Nr. 4, p. 671, 1996.

[32] A. Yatawatta, „Reduction en masse of inguinal hernia: a review of rare and potential fatal complication following reduction of inguinal hernia," *BMJ Case Reports,* Nr. bcr2017220475, 2017.

[33] R. J. Fitzgibbons und A. Fase, „Groin hernias in adults," *N Engl J Med,* Bd. 372, pp. 756-763, 2015.

[34] M. Simons, „European hernia Society guidelines on the treatment of inguinal hernia in adult patients.," *Hernia,* Bd. 13, Nr. 4, pp. 343-403, 2009.

[35] M. Memon, N. Cooper, B. Memon, M. Memon und K. Abrams, „Meta-analysis of randomized clinical trials compairing open and laparoscopic inguinal hernia repair," *Br J Surg,* Bd. 90, pp. 1479-1492, 2003.

[36] D. Shell, J. A. P. de la Torre und L. Vasconez, „Open repair of ventral incisional hernias," *Surg Clin North Am ,* Bd. 88, Nr. 1, pp. 61-83, 2008.

[37] R. Luijendijk und W. v. d. T. M. Hopp, „A comparison of suture repair with mesh repairfor incisional hernia," *N Engl J Med,* Bd. 343, Nr. 6, pp. 392-8, 2000.

[38] F. Albino, K. Patel, M. Nahabedian, M. Sosin, C. Attinger und P. Bahanot, „Does mesh location matter in abdominal wall reconstruction? A systematic review of the literature and a summary of recommendations.," *Plast reconstr surg,* Bd. 132, Nr. 5, p. 1295, 2013.

[39] F. Muysoms, M. Miserez, F. Berrevoet, G. Campanelli und e. al, „Classification of primary and incisional abdominal wall hernias," *Hernia,* Bd. 13, Nr. 4, p. 407, 2009.

[40] O. Ramirez, E. Ruas und A. Dellon, „"Components separation" method for closure of abdominal-wall defects: an anatomic and clinical study.," *Plast Reconstr Surg,* Bd. 86, Nr. 3, pp. 519-26, 1990.

[41] K. LeBlanc und W. Booth, „Laparoscopic repair of incisional abdominal Hernias using polytetrafluoroethylene: preliminary findings.," *Surg Laparosc Endosc,* Bd. 3, pp. 39-41, 1993.

[42] V. Zhang, H. Zhou, Y. Chai, C. Cao, K. Jin und Z. Hu, „Laparoscopic versus open incisional and ventral hernia repair," *World J Surg,* Bd. 38, pp. 2233-40, 20114.

[43] K. LeBlanc, M. Elieson und J. 3. Corder, „Enterotomy and mortality rates of laparoscopic incisional and ventral hernia repair: a review of the literature," *JSLS,* Bd. 11, Nr. 4, pp. 408-14, 2008.

[44] K. LeBlanc, „Laparoscopic incisional and ventral hernia repair: complications: how to avoid and handle," *Hernia,* Bd. 8, pp. 323-331, 2004.

[45] E. Misiakos, P. Patapis, N. Zavras, P. Tzanetis und A. Machairas, „Current Trends in Laparoscopic Ventral Hernia Repair.," *JSLS,* Bd. 19, Nr. 3, 2015.

[46] G. Kohn und e. al, „Guidelines for the management of hiatal hernia," *Surg endosc,* Bd. 27, Nr. 12, pp. 4409-28, 2013.

[47] F. Schlottmann, P. Strassle, T. Farrell und M. Patti, „Minimally invasive surgery should be the standard of care for paraesopahageal hernia repair," *J Gastrointest Surg ,* Bd. 21, Nr. 5, pp. 778-84, 2017.

[48] C. Daigle, P. Funch-Jensen, D. Calatayud, P. Rask, B. Jacobsen und T. Grantcharov, „laparoscopic repair of paraesophageal hernia with anterior gastropexy: a multi center study," *Surg Endosc,* Bd. 29, Nr. 7, pp. 1856-61, 2015.

[49] D. Prassas, T. Rolfs und F. Schumacher, „ Laparoscopic repair of giant hiatal hernia. A single center experience.," *Int J Surg,* Bd. 20, pp. 149-152, 2015.

[50] D. Prassas, T. Rolfs, N. Sirothia und F. Schumacher, „Lightweight Titanium-coated Mesh Versus Standard-Weight Polypropylene Mesh in Totally Extraperitoneal Inguinal Hernia Repair (TEP): A Cohort Analysis.," *Surg Laparosc Endosc Percutan Tech.,* Bd. 26, pp. e113-e116, 2016.

[51] D. Prassas, A. Ntolia, J. Brosa, A. Kounnamas, T. Rolfs, F. Schumacher und A. Krieg, „Effect of Previous Lower Abdominal Surgery on Outcomes Following Totally Extraperitoneal (TEP) Inguinal Hernia Repair.," *Surg Laparosc Endosc Percutan Tech.,* Bd. 29, pp. 267-270, 2019.

[52] D. Prassas, T. Rolfs, W. Knoefel und A. Krieg, „Meta-analysis of totally extraperitoneal inguinal hernia repair in patients with previous lower abdominal surgery.," *Br J Surg,* Bd. 106, Nr. 7, pp. 817-823, 2019.

[53] D. Prassas und F. Schumacher, „Electric cauterization of the hernia sac in laparoscopic ventral hernia repair reduces the incidence of postoperative seroma: a propensity score-matched analysis," *Hernia,* Bd. 22, Nr. 5, pp. 747-750, 2018.

[54] R. Stadlhuber, A. Sherif, R. J. Fritzgibbons, M. Brunt, J. Hunter, T. Demeester, L. Swanstrom, C. Daniel Smith und C. Filipi, „Mesh complications after prosthetic reinforcement of hiatal closure: a 28-case series," *Surg Endosc,* Bd. 23, Nr. 11, pp. 2499-504, 2009.

[55] B. Oelschlager, C. Pellegrini, J. Hunter, M. Brunt, N. Soper, B. Sheppard, N. Polissar, M. Neradilek, L. Mitsumori, C. Rohrmann und L. Swanstrom, „Biologic prosthesis to prevent re-currence after laparoscopic paraesophageal hernia repair: long-termfollow-up from a multicenter, prospective, randomized trial. (PDF) Laparoscopic Paraesophageal Hernia Repair: Utilization Rates of Mesh in the USA and S," *J AmColl Surg,* Bd. 213, Nr. 4, pp. 461-8, 2011.

[56] B. Müller-Stich, V. Achtstätter, M. Diener, M. W. R. Gondan, F. Marra, A. Zerz, C. Gutt, M. Büchler und G. Linke, „Repair of paraesophageal hiatal hernias - is a fundoplication needed? A randomized controlled pilot trial.," *J Am Coll Surg,* Bd. 221, Nr. 2, pp. 602-10, 2015.

[57] F. Usher, J. Hill und J. Ochsner, „Hernia repair with Marlex mesh. A comparison of techniques.," *Surgery,* Bd. 46, pp. 718-24, 1959.

[58] D. Earle und L. Mark, „Prosthetic material in inguinal hernia repair: how do I choose?," *Surg Clin North Am,* Bd. 88, Nr. 1, pp. 179-201, 2008.

[59] C. Brown und J. Finch, „Ehich mesh for hernia repair?," *Ann R Coll Surg Engl,* Bd. 92, Nr. 4, pp. 272-8, 2010.

[60] W. Cobb, K. Kercher und B. Heniford, „The argument for lightweight polypropylene mesh in hernia repair," *Surg innov,* Bd. 12, Nr. 1, pp. 63-9, 2005.

[61] J. Burgmans, C. Voorbrood und R. Simmermacher, „Long-term results of randomized double-blinded prospective trial of a lightweight (Ultrapro) versus a heavyweight mesh (Prolene) in laparoscopic total extraperitoneal inguinal Hernia repair (TULP-trial)," *Ann Surg,* Bd. 263, pp. 862-866, 2006.

[62] S. D. G. Davis Jr und A. Bates, „Chapter 8: How to choose a mesh in hernia repair," in *The SAGES manual of hernia surgery*, Springer, 2019, pp. 97-107.

[63] S. Davis Jr, G. Dakin und A. Bates, „Minimally invasive Surgical techniques for inguinal hernia repair," in *The SAGES manual of hernia surgery*, Springer, 2019, p. 459.

[64] S. Chung, C. Huang, S. Chueh, Y. Tsai und H. Yu, „Feasibility and safety of total extraperitoneal inguinal hernia repair after previous lower abdominal surgery: a case–control study.," Bd. 25, p. 3353–3356, 25 2011.

[65] J. Elshof, F. Keus, l. J. Burgmans, G. Clevers, P. Davids und T. van Dalen, „ Feasibility of right-sided total extraperitoneal procedure for inguinal hernia repair after appendectomy: a prospective cohort study," Bd. 23, p. 1754–1758., 2009.

[66] H. I. Parker, J. Nottingham, R. Bynoe und M. Yost, „Laparoscopic repair of large incisional hernias.," *Am Surg,* Bd. 68, pp. 530-3, 2002.

[67] D. Birch, „Characterizing laparoscopic incisional hernia repair," *Can J Surg,* Bd. 50, pp. 195-201, 2007.

[68] K. Suwa, T. Okamoto und K. Yanaga, „Closure versus non-closure of fascial defects in laparoscopic ventral hernia and incisional hernia repairs: a review of the literature," *Surg Today,* Bd. 46, Nr. 7, pp. 764-773, 2016.

[69] M. Zeichen, H. Lujan, W. Mata, V. Maciel, D. Lee, I. Jorge, G. Plasencia, E. Gomez und A. Hernandez, „Closure versus nonclosure of hernia defect during laparoscopic ventral hernia repair with mesh.," *Hernia,* Bd. 17, pp. 589-96, 2013.

[70] M. Clapp, S. Hicks, S. Awad und M. Liang, „Trans-cutaneous closure of central defects (TCCD) in laparoscopic ventral hernia repairs (LVHR)," *World J Surg,* Bd. 37, pp. 42-51, 2013.

[71] J. Lambrecht, A. Vaktskjold, E. Trondsen, O. Øyen und O. Reiersten, „Laparoscopic ventral hernia repair: outcomes in primary versus incisional hernias: no effect of defect closure," *Hernia,* Bd. 19, Nr. 3, pp. 479-86, 2015.

[72] E. Tsimoyiannis, K. Tsimogiannis, G. Pappas-Gogos, K. Nikas, E. Karfis und H. Sioziou, „Seroma and recurrence in laparoscopic ventral hernioplasty.," *JSLS,* Bd. 12, Nr. 1, pp. 51-7, 2008.

8. EIDESSTATTLICHE VERSICHERUNG

Ich versichere an Eides statt, dass die Habilitationsschrift selbstständig und ohne unzulässige fremde Hilfe erstellt worden ist und die hier vorgelegte Arbeit nicht von einer anderen Medizinischen Fakultät abgelehnt worden ist.

Dr. med. Dimitrios Prassas

9. APPENDIX

The present cumulative work was based on the following original publications:

Appendix A:
D. Prassas, T. Rolfs und F. Schumacher, „ Laparoscopic repair of giant hiatal hernia. A single center experience.," *Int J Surg,* Bd. 20, pp. 149-152, 2015.

Appendix B:
D. Prassas, T. Rolfs, N. Sirothia und F. Schumacher, „Lightweight Titanium-coated Mesh Versus Standard-Weight Polypropylene Mesh in Totally Extraperitoneal Inguinal Hernia Repair (TEP): A Cohort Analysis.," *Surg Laparosc Endosc Percutan Tech.,* Bd. 26, pp. e113-e116, 2016.

Appendix C:
D. Prassas, A. Ntolia, J. Brosa, A. Kounnamas, T. Rolfs, F. Schumacher und A. Krieg, „Effect of Previous Lower Abdominal Surgery on Outcomes Following Totally Extraperitoneal (TEP) Inguinal Hernia Repair.," *Surg Laparosc Endosc Percutan Tech.,* Bd. 29, pp. 267-270, 2019.

Appendix D:
D. Prassas, T. Rolfs, W. Knoefel und A. Krieg, „Meta-analysis of totally extraperitoneal inguinal hernia repair in patients with previous lower abdominal surgery.," *Br J Surg,* Bd. 106, Nr. 7, pp. 817-823, 2019.

Appendix E:
D. Prassas und F. Schumacher, „Electric cauterization of the hernia sac in laparoscopic ventral hernia repair reduces the incidence of postoperative seroma: a propensity score-matched analysis," *Hernia,* Bd. 22, Nr. 5, pp. 747-750, 2018.